Instruments

THE MAGAZINE OF

Measurement and Control

Vol. 15
NOV.
1942
No. 11

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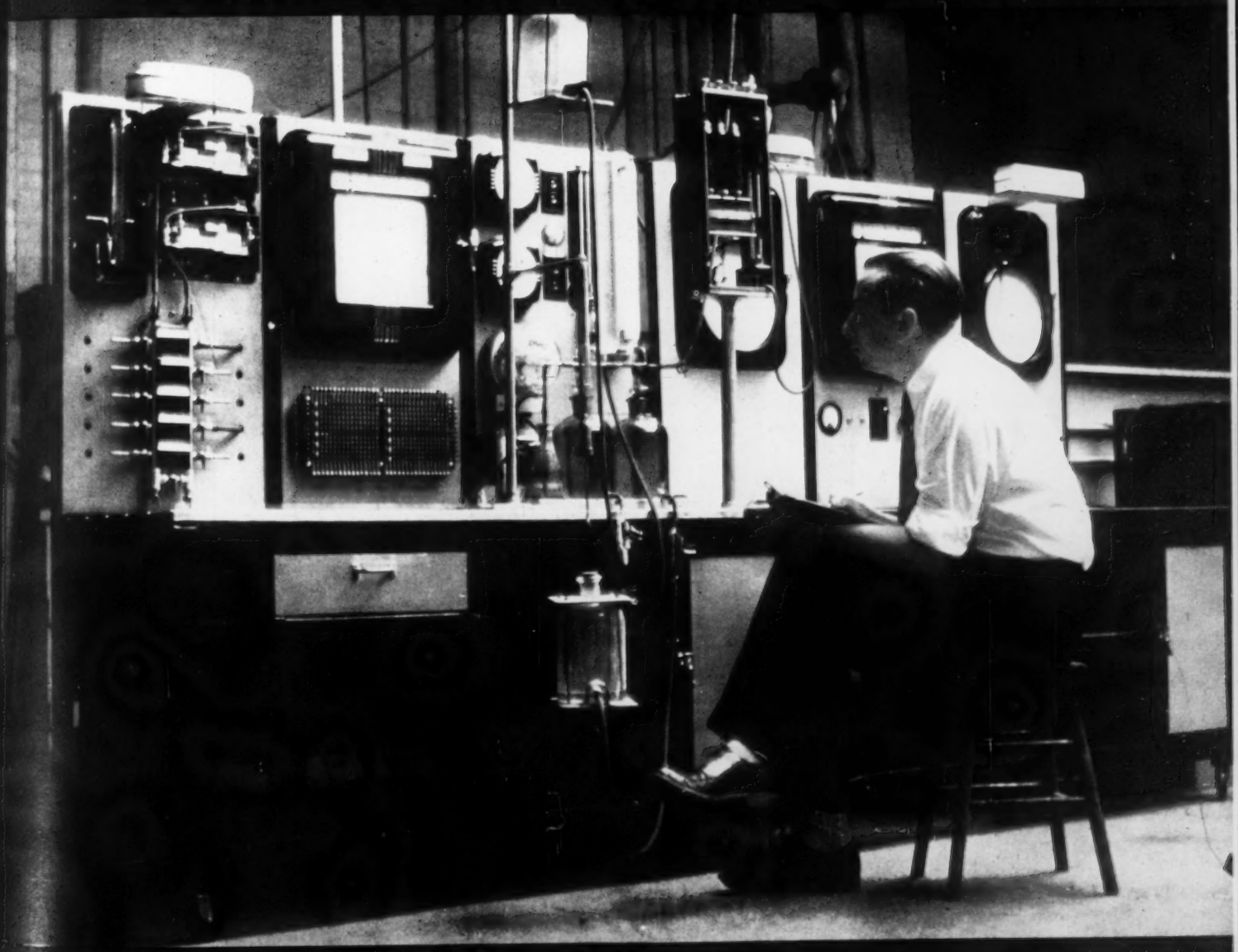

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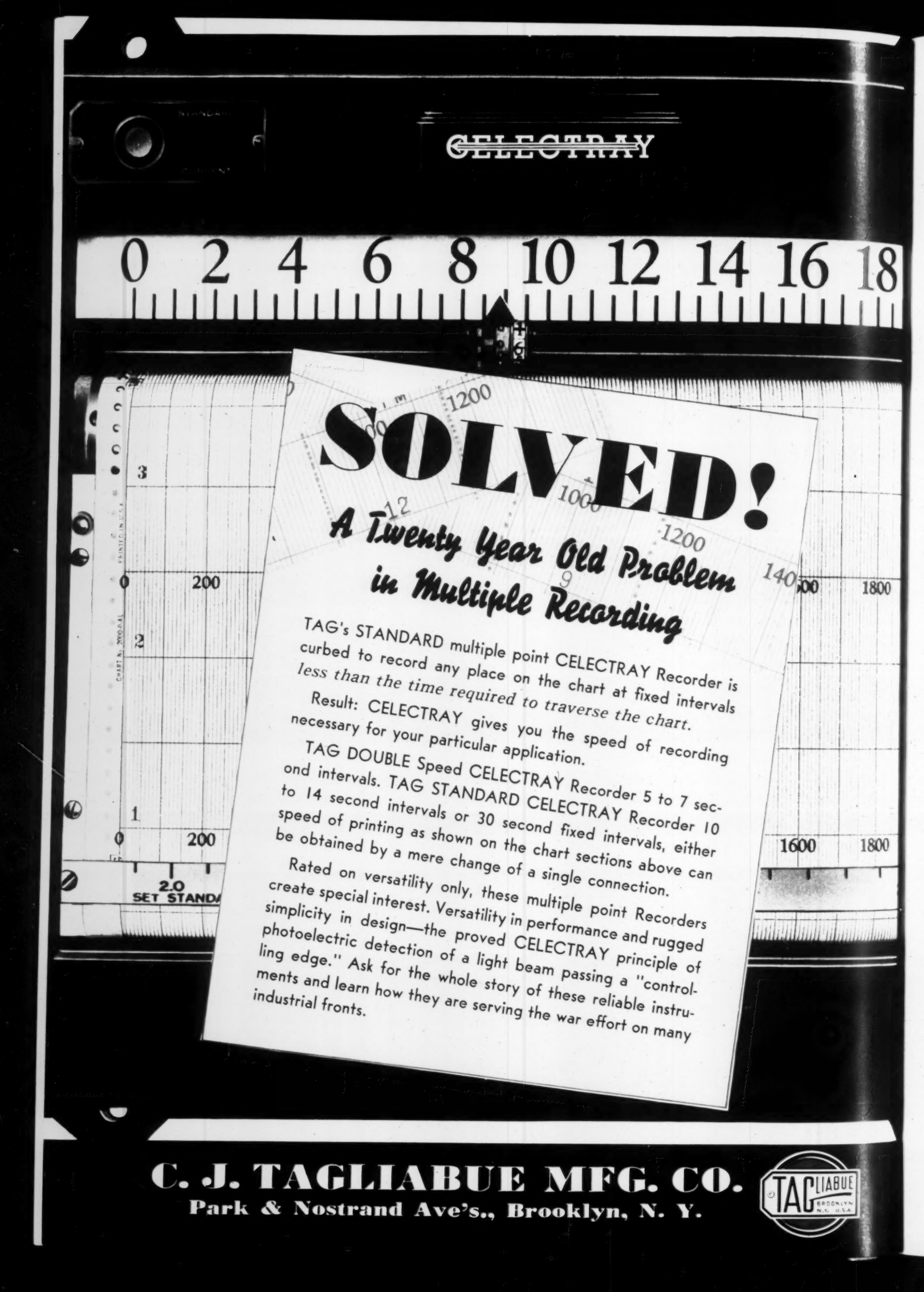
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Instruments THE MAGAZINE OF Measurement and Control

M. F. BEHAR, Editor

General Man-power Needs; Individual Decisions

IN the last two or three months, as the needs of Army, Navy, Coast Guard, Mercantile Service, manufacturing industries, transportation industries, food industries and farmers became acute, we have been receiving letters from subscribers asking for our advice. Here are samples.

To the Editor of *Instruments:*

I am an electrical instrument repairman, employed at the R. C. A. Manufacturing Company, Camden, N. J., and have been considering enlisting in the Armed Forces.

Due to the scarcity of skilled instrument repairmen at the present time, I feel that I would be most useful to the service doing the same type of instrument repair work. . . . I believe that there must be some provision for the repair of electrical instruments in the service, and would appreciate advice from you. S. D. H., Philadelphia, Pa.

To the Editor of *Instruments:*

I have been told that there is a great demand for Instrumentation Engineers in the Army and Navy Air Corps. I am draft age and expect to be called within the next two months: can you send me any advice on how and where to apply for this kind of position? I am employed at the Michigan Chemical Corp. now. I had two years college, 6 weeks training at Brown Instrument Co. school, one year chemical drafting and six months instrument installation and repair at M. C. Corp. G. P., St. Louis, Michigan

To the Editor of *Instruments:*

Can you give us an article on just what the needs of the Armed Forces are for instrumenticians?

Many of us working at industrial instrumentation may be able to do more for our country by following our profession as a member of the Armed Forces or as a civilian employee at a domestic or foreign base.

Do the Army and Navy use instruments for the measurement and control of temperature, pressure, flow and liquid level? Are they electrical, hydraulic, pneumatic or mechanical? Is there a place in the armed forces for instrumenticians with experience in oil refining? Steel? Aluminum?

You are in a better position than anyone to answer the above and many more questions. You will help many of us to make a decision and will help the country by getting qualified and experienced men into those outfits where they can be of the most help.

A mention of the ratings that are available would also help. W. W., Los Angeles, Calif.

It is not our province to interfere with solemn decisions that every individual subscriber should make for himself. We can only venture a few words of general advice. In our opinion, the most important factor which should guide each individual is to make a decision whereby his skill will be used in defeating the enemies of America. We assume that nearly every subscriber who possesses a particular skill with instruments is exercising this skill either in industry or in the Armed Forces.

If he is already in the Armed Forces, there is nothing more for him to do unless he is certain that his skill is not being used to the utmost—in which case he should take up the question of a transfer with his superior officers—not with *Instruments.*

If he is employed in industry, he should solemnly ask himself whether he is certain that his particular skill, after he leaves his present occupation, would be used to better advantage in winning the war. In such a case, therefore, his decision would hinge on whether or not he is employed in a "war industry." This is often difficult to determine because there is no sharp dividing line between war *occupations* and non-essential occupations.

Some older subscribers who hold responsible positions, are classified as key employees *and are still of draft age,* itch to get into uniform but—for patriotic rather than selfish reasons—prefer to be commissioned as officers and assigned to aeronautical or ballistics laboratories, etc. They would not kick if they were sent to kill Japs and Nazis with rifles and bayonets, for they are still young and ready for physical heroism, but their mature minds keep them from cutting loose without reasonable certainty of being made technical officers. *Instruments* cannot deal with individual cases. Here are general factors:

(1) As a rule, the individual should recognize his own local draft board as the agency officially set up to weigh the needs of the Army and of local industries.

(2) As a rule, if a key employee applies for a commission, he is told to get a letter of release from his company, which makes him subject to induction.

(3) Physical examinations for commissioned officers are much more rigid than for enlistees or selectees. An applicant's engineering reputation cuts no ice with the medical boards. If he fails to pass, he becomes available for induction because his employer had released him.

(4) The need of technical officers with specialized civilian experience varies from branch to branch and from time to time. You might have heard, for example, that the Navy needs officers for developing a new secret detector, but perhaps that particular work was completed before the report or rumor reached you.

Many subscribers — especially young ones — already made their decisions. They intend to join the Armed Forces and nothing will stop them. All they want to know is whether to join this or that arm or service, whether to enlist or to try for a commission, etc. It is not our function to interfere with these decisions, even when we feel that the individual possesses a skill which is valuable in the war industries. Nor is it our function to express any preference for any arm or branch of any service. If a young subscriber who is a highly trained instrument man and classed as a key employee by his company has made up his mind to enlist in an infantry regiment where he will have a chance to fight with rifle and bayonet, we can only admire and respect his courage and patriotism and hope that his place at the instrument board or testing room will be filled.

[Personally, your editor sympathizes with those who want to join the Armed Forces. Since the age of eighteen when I enlisted in a National Guard infantry regiment, I have been in the military service. I had four and one-half years of active service (1916-1920) which included twenty-two months under Pershing. I had eleven periods of active-service training between 1923 and

1941 and served on various Army Boards without pay. Immediately after Pearl Harbor I got my orders, was turned down by the Army doctors, underwent treatment in an attempt to correct the deficiencies, filed an appeal with the Medical Board of Appeals in Washington but was finally turned down by this "medical supreme court." Yes, I certainly sympathize with those who want to get into uniform! But it is my duty to tell them what my own superior officers have told me: "You are many times more valuable in your various civilian jobs, helping a number of war industries, than you would be in charge of Department 89, Building 17, Arsenal No. 5."]

However, for the information of the greater number of subscribers who wish to do instrument work (or similar skilled work) in the Armed Forces, we call attention to the need of this work in the various Services. Evidently, a number of subscribers did not see the references to this need which appeared in the newspapers; they have not heard the announcements occasionally made on the radio. Therefore, we take pleasure in printing three of the releases which bear on this subject:

ARMY SEEKS 100,000 MECHANICS TO MEET IMMEDIATE NEEDS

[W. D. Press Branch Release]

An intensive recruiting campaign has been launched by the Army to enlist 100,000 skilled mechanics and technicians for service in the Army Air Forces, the Signal Corps and the Ordnance Department. . . . Successful applicants will receive supplemental on-the-job training to qualify them for Army Technician ratings. . . .

All applicants must be male citizens of the United States between the ages of 18 to 44 inclusive, and all must obtain clearance from their local Selective Service Boards. They must be qualified for general military service as determined by current physical standards.

For service in the Signal Corps or Ordnance Department, applicants must have the same educational qualifications as for general enlistment in the Army and must present proof of their technical skills through past experience, employment and training.

For enlistment in the Army Air Forces, a special application form has been prepared, stating the main and secondary occupational specialties of the applicant. These applicants will receive an intelligence test, and if found acceptable will get an oral trade test by the United States Employment Service.

While the men will be enlisted as privates, in view of their skills, it is expected that most of them will shortly receive Non-Commissioned Officer or technician ratings, and rapid promotion may be expected. Some of the men in the Army Air Forces will be on flying status and draw 50% extra base pay.

Pay scales range from $50 a month for a private to $138 a month for a master sergeant. In addition there are family allowances for men with dependents. The Army pays all a soldier's expenses, including quarters, food, clothing, medical care and on-the-job training.

Technicians are vitally needed at once, chiefly for maintenance work and as a stop-gap until the training schools of the Nation begin turning out men in sufficient volume. Men interested should apply to the nearest Recruiting Station for further information.

For enlistment in the Army Air Forces men should be able to qualify if they are experienced in any of the following trades:

[EDITOR'S NOTE—Only three of the many listings are printed here.]

Bench Assembler—electrical and radio equipment, office machine, household appliance, instruments of all kinds.

Instrument Maker or Repairman—household appliance, electrical equipment, electric motor, meter, measuring instrument, and others.

Watch or Clockmaker and repairman.

Similarly, the Signal Corps and Ordnance Department seek men of the varied skills to meet their peculiar needs.

In order not to take any key men from essential war industries, no man will be accepted for enlistment unless he obtains clearance from his local Selective Service Board.

THE NAVY NEEDS MEN!

By Rear Admiral RANDALL JACOBS, U.S.N.
Chief of the Bureau of Naval Personnel

From our tiny beginnings in 1775 we have built the greatest navy in the world. . . . It is a well-knit team of mighty battleships, aircraft carriers, cruisers, destroyers, submarines and various smaller units. These ships govern the seas, while overhead flies a vast umbrella of naval aircraft—fighters, dive-bombers, long range flying boats and torpedo planes.

To service the sea and air arms of the Navy we have built a world-wide network of fuel and supply stations. For the Navy means more than ships and planes. It means bases for tankers, transports and hospital ships. It includes drydocks, wharves, machine shops, ramps, anchorages and barracks. It's a vast fleet of armed merchant ships carrying weapons of war across the seas, and a great system of steel mills, factories, arsenals and ordnance depots. The Navy has a thousand and one jobs to do in order to win this war and for all of them it needs enlisted men.

The Navy is prepared to give the men who attend its schools a training worth over fifteen hundred dollars. The men who enlist in the Navy today will be well prepared to hold a good job in civil life after the war. . . . Many men prominent in American life today got their start as enlisted men in the Navy. Among these are . . . Thomas A. Morgan, President of the Sperry Gyroscope Corporation.

The Navy advances its men as rapidly as possible. Today over fifty percent of the men in the Navy are Petty Officers. Anyone who has had particularly useful experience or training may qualify immediately for a Petty Officer's rating with the higher pay and allowances to which their experience entitles them.

THE RIGHT MAN FOR THE RIGHT JOB

By Major General JAMES A. ULIO,
The Adjutant General of the Army

"Occupation?" asked the young corporal interviewing new soldiers at a California reception center.

"Attorney," answered the selectee.

The corporal sighed heavily. There is scant place for lawyers as such in our Army. The Judge Advocate General's Department has long since been filled and its waiting list is voluminous. The corporal continued his questioning, but now he wondered where this new registrant might best fit.

At last the interviewer came to bracket number 15 on the Soldiers' Qualification Card. "Any hobbies?" he asked.

The selectee hesitated. Then he said. "I have a model railroad in my basement at home."

The interviewer perked up.

"Do you assemble the cars and engines yourself?"

Now the selectee was getting into the spirit of the thing.

"Yes, and I wire the tracks and signals and rheostats," he replied.

There was no hesitation in the way the corporal wrote "INSTRUMENT REPAIRMAN" in the place on the selectee's card reserved for the initial duty or training assignment recommended for him. Today this particular selectee, who in civilian life was a lawyer, is a technical sergeant at a big American air base, playing an important part in keeping our bombers and pursuit planes flying. He feels he has found his proper niche in the vast Army we are training, and his superiors have recommended him for Officers' Candidate School.

This is a typical example of the way in which the skills, talents and ingenuity of millions of Americans are being blended into the varied pattern of Army life. "The Right Man for the Right Job"—that sign hangs on the wall of our reception and replacement training centers, where Army recruits are sorted and classified according to their occupational experience, education, potential ability and general background.

Within the limits of human shortcomings, the American Army in this war is making the maximum use of the talent

and ...ities at its disposal. No effort is being spared to put the ... man in the right job. . . .

M... than 5,000 officers and enlisted men in the Army are now ...gaged in personnel classification and assignment work. Others are being trained as rapidly as possible. They are ... who take pride in putting new soldiers where they belong. . . .

In the War Department buildings at Washington psychologists and technical experts are constantly devising new tests designed to discern aptitudes and talents in soldiers. Occupations and jobs also have been broken down. . . .

My advice to the man entering the Army is to probe all the recesses of his mind for experiences which may prove useful in his classification; do not rule out anything. . . .

No Army ever had as many skills or so much knowledge available as the American Army which is fighting this war. The average soldier of today brings with him three years more of schooling than the average soldier of the first World War. . . .

These comparatively high educational attainments impose a responsibility on the Army, a responsibility to use to the utmost the knowledge and skills which this education has developed. Never were men entering military service checked and classified more carefully. To permit a talent or ability to go unnoticed is a grave offense against both the soldier and the Army. With this thought in mind, the personnel men of the War Department are doing their work. The soldier registering for duty may be sure that any capability or skill which he can demonstrate will be put to immediate and effective use. As our 4,000,000 soldiers—and more to come—are sorted and classified, the slogan of the classifiers is "The Right Man for the Right Job."

Substitutes for Strategic and Critical Materials

This, too is an editorial, though actually it is the substance of a talk at the Gibson Island Research Conference on Instrumentation of the American Association for the Advancement of Science, August 25, 1942, by H. P. ROCKWELL, Jr., Chief of Combat Instrument Unit, Instrument Section, War Production Board

SEVERAL services to industry are performed by the Instrument Section of the War Production Board. The foremost consideration is assisting industry to fulfill the requirements of the armed forces.

The smooth flow of raw materials is essential to the increasing production required by military demands. As long as the requirements of the armed services are large, materials will be scarce, at least until the labor reserve is completely absorbed.

In order, therefore, to keep materials flowing to all essential uses, it is necessary to conserve those materials that are scarce. The Bureau of Industrial Conservation of the War Production Board supplies a schedule of materials from time to time, showing the relative scarcity of each. It is wise to obtain a copy of this list for first-hand information.

Nearly all foresighted companies have already instituted a program of substitution, in order to eliminate the use of scarce materials wherever possible. Many manufacturers have found that a few moments spent listing the savings effected by such substitutions are well worth-while. This is true particularly when they find it necessary to ask for a quantity of urgently required materials. Together with its consultants, the Instrument Section has found a relatively simple way to present the substitution savings in the manufacture of instruments. Generally speaking, there are four parts common to all instruments:

1. Case and Base,
2. Fixed Element,
3. Moving Element,
4. Accessories.

Usually the greatest saving can be made in the parts that make up either the case or the base, and since the instrument parts are usually smaller, lesser savings can be made. The moving element of most instruments is small by comparison, and hence, frequently not as fruitful a source of material saving. It should be remembered that while the saving of material is important, production of instruments for War equipment is equally important, so that a careful balance should be established to be sure that production is not sacrificed to saving a few ounces of material. Another important consideration is that, in general, many years of experience has gone into the manufacture of instruments, particularly in their moving elements, and the value of that experience should not be cast aside unless a notable saving can be effected.

However, on those instrument parts falling into any of the four categories above, on which substitutions have been or can be made, it is wise to list each part involved down the left-hand side of a sheet of paper, and list the critical materials that have been or can be saved by the substitution, each in a separate column across the top of the page. Now, opposite each part, show the material that has been substituted for the scarce material and, if possible, the percent of saving effected. After such a tabulation has been made, it is possible to add up the percent of each scarce material that has been saved, and in many cases an impressive total is the result. For instance, some companies have been able to save, by judicious substitution, as much as 85 percent of all of the rubber that they formerly used. Other companies have eliminated as much as 40 percent of the copper they formerly used, and savings have been reported on even such small but important items as jewel bearings, for which glass and new alloys have been substituted. But even if only a few percent saving results, it will still be a contribution when viewed across the entire industry.

One of the means of obtaining materials for War production is the Production Requirements Plan, or the PD 25 A report form. When your tabulation of substitutions is complete, it is worthwhile to attach a copy of the tabulation directly to your PD 25 A to show the savings you have achieved. In addition, it is worth-while to show the end use pattern as outlined in Priority Regulation No. 10 when you require scarce materials such as aluminum, copper, etc. In addition, since the armed forces need many more instruments than are available today, all but the most essential uses of instruments should be eliminated from your production to leave room for the manufacture of military needs.

The Instrument Section is ready and willing to assist instrument makers with their questions, and to point out which items are most urgently needed for the effective prosecution of total war.

An Instrument Panel for Combustion Tests of Domestic Fuel-burning Equipment

By P. R. WISCHNEF and R. C. CROSS

Chief Engineer Mechanical Division Senior Combustion Engineer
Technical Laboratories, Sears, Roebuck and Co., Chicago, Illinois

THE instrument panel described in this article was developed to meet the needs of a combustion laboratory where tests are conducted on a wide variety of domestic fuel burning equipment. All types of solid fuels, oil, and gas are utilized in the test program. Because of this range in equipment, and fuels, it was essential that laboratory instrumentation be flexible, and mobile.

A number of laboratory tables were constructed with removable sectionalized back panels, each panel being 20" × 36". The laboratory instruments were mounted on the individual panels. In this manner, various combinations of instrument assemblies can be easily effected.

The instrument set-up shown [cover photograph] is representative of a complete assembly for obtaining the essential data in combustion testing. Equipment for measuring and recording drafts, temperatures and smoke density is contained in the assembly, as well as a constant-rate flue-gas collection system, conventional flue-gas analyzer, watt-hour meter, wet- and dry-bulb thermometer set, timer clocks and interval reminder.

The left-hand panel in the table in the foreground has two inclined draft gages of 0 to 0.5" water range, and a 10" vertical manometer. The manometer switch mounted in the lower section of the panel permits the rapid determination of drafts or pressures, at as many as ten locations.

Temperature recording equipment is located on the center panel. A six-point recording potentiometer, calibrated for iron-constantan thermocouples, is used. This instrument has automatic cold junction compensation, and is of dual range, 0-500°F. and 0-1000°F. The bus-bar board has 32 thermocouple connections, and permits the connection of individual couples, or a number of couples, in series or in parallel connection, to any desired combination of points on the recorder. This arrangement has been found to be very convenient.

A general-utility panel is located on the right hand end of the table. The upper electric clock is used for conventional time measurement. The lower clock is wired to a standard duplex receptacle. The aggregate operating time of a device, such as an oil burner, or stoker, can be measured by running an electrical connection from the load side of the device to this receptacle.

A special watt-hour meter, direct reading to 0.1 kilowatt-hour, is mounted on the lower section of the panel. Suitable receptacles for 110-volt 60-cycle supply, and plug-in for device under test are provided for power measurement. The duplex receptacles provide a convenient means for connecting a voltmeter. A combination switch and outlet is wired in the hot line for ammeter connection. The switch is used for closing the circuit when ammeter is not in use.

The properties of air for combustion are determined by means of a wet- and dry-bulb thermometer set. The air is circulated over the thermometer bulbs by means of an automobile windshield fan mounted on the rear of the panel. A separate 110-to-6-volt step-down transformer is used for the fan motor.

A conventional flue gas analyzer, or Orsat, is used for the determination of carbon dioxide, oxygen, and carbon monoxide in the flue gases. To facilitate the operation of this unit, an 18" fluorescent lamp is mounted on the panel directly in line with the Orsat measuring burette.

The constant-rate flue gas collecting system is patterned after that originally developed by the Bureau of Mines, Pittsburgh Station, Fuels Section. A small rotary pump, driven by a ⅛-h.p. motor mounted beneath the table top, is used to draw a gross sample of flue gas from the stack. The bottle system, shown at the left of the Orsat, is so arranged as to draw a representative sample of gas at a constant rate. Each bottle is of 2000 milliliter capacity, and a sample of this volume can be drawn as a snap sample, or over periods as long as two hours, depending upon the height differential between the fixed and spring-supported bottles. One set of two bottles is used for collecting the sample, while the other set is passing the sample to the Orsat for analysis.

The necessity for collecting periodic samples over measured time intervals when burning solid fuels has been pointed out in the literature. The accuracy of time-weighted gas analysis data obtained by the above outlined method is very desirable.

The end panels on the right-hand table are each equipped with a recording draft gage, range 0.05" water pressure to 0.25" water draft. These recorders have reversible connections for draft and pressure, giving them considerable versatility.

The center panel is used for the smoke density recorder, and electrical control circuit. The smoke recorder is of the photoelectric type and is a modified form of similar instruments developed by the Fuels Division of Battelle Memorial Institute. The essential elements of the recorder are a smoke sampling tube, containing a light source and photoelectric cell, electrical circuit for the light source, and a recording potentiometer of special range.

The smoke sampling tube is mounted on the smoke pipe leading from the device under test, and is readily adapted to smoke pipes of various diameters. A high-pressure air aspirator, supplied by house service line, draws a representative sample of smoke from the center of the smoke pipe, passing it for a fixed distance between the light source and the photoelectric cell, and discharging it back into the smoke pipe beyond the sampling point. Because of the fixed length of the smoke column the sample is not influenced by stack diameter and, thus, possesses the desirable flexibility.

A light source, in this case a standard 50-candle-power 6-8 volt automobile spotlight bulb, is mounted in one end of the smoke measuring tube. The light is intensified by a pair of plano-convex lenses and focused on the face of a copper oxide self-generating photocell mounted in the opposite end of the tube. Suitable cover glasses, and water jacket for prevention of overheating the cell, are also incorporated in the tube.

The intensity of the light that falls upon the cell, when the tube is clear of smoke, is maintained constant by means of an electrical control circuit. This circuit contains a line voltage stabilizer, 110-to-7.5-volt step-down transformer and potentiometer-type rheostat.

In operation, as the smoke density in the tube changes the light intensity received by the photocell, the voltage output of the cell varies and is recorded by the recording potentiometer. This instrument is equipped with a special scale reading in terms of smoke concentration from zero to infinity, the basis for the scale being that unity equals 10 percent absorption of the initial illumination. Calibration in Ringelmann numbers is also provided.

In addition to the instruments previously described, the laboratory is completely equipped with the necessary scales and meters for measurement of fuel quantities. When burning solid fuels, the device under test is mounted on scales so that the rate of burning of combustible can be determined directly by weight loss.

Boiler test outputs are determined by standard condenser systems in accordance with recognized codes. The output of

(Continued on page 49)

The Stem Lag of Industrial Thermometers

By BRADFORD NOYES
Physicist, Taylor Instrument Companies, Rochester, N. Y.

1. The Newton-Harper Law

USERS of long-stem industrial thermometers have been troubled by the time required for a thermometer, suddenly plunged into a hot liquid, to reach equilibrium. Although manufacturers have attempted in many ways to reduce this time, none, so far as is known, has isolated the various factors involved, studied every one separately, and published the findings.

The Law of Heat Transfer was first enunciated by Newton. In 1912, D. R. Harper[1] published a clear exposition of the mathematics involved, particularly as applied to a simple thermometer and to the Beckman types.

If a simple thermometer be plunged into a bath held at a different temperature, its readings follow the equation—

$$\frac{\theta-\omega}{\theta_0-\omega} = e^{-(1/L)t} \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where ω is the temperature of the bath, θ_0 is the original temperature of the thermometer, θ is the instantaneous temperature of the thermometer (as shown by its reading) at time t, e is the natural logarithmetic base, and L is what may be called the lag of the thermometer. To quote from Harper:—

> If a thermometer has been immersed for a long time in a bath whose temperature is rising at uniform rate, L is the number of seconds between the time when the bath attains any given temperature and the time when the thermometer indicates this temperature. In other words, it is the number of seconds the thermometer "lags" behind such a temperature.
>
> If a thermometer be plunged into a bath maintained at a constant temperature (the thermometer being initially at a different temperature), L is the number of seconds in which the difference between the thermometer reading and the bath temperature is reduced to $1/e$ times its initial value.

Expressed as a percentage, $1/e$ is 36.8 percent; thus L is the number of seconds in which the initial difference is reduced to 36.8 percent; but it is customary also to state it the other way and to define L as the time for the reading to cover 63.2 percent of the initial difference. Similarly, L_{90} and L_{99} will be used to denote the times for 90 percent and 99 percent of the initial difference to be reached.

Inspection of Equation (1) shows that if a thermometer be plunged into a constant-temperature bath and read periodically, and if these readings be substracted from the temperature of the bath and plotted as ordinates on semi-log paper (time being the abscissa) a straight line should result. The slope of this line represents the lag L of the thermometer.

Harper showed that the lag of a simple thermometer depends upon the following factors:

1. Size and shape of the bulb.
2. Material of the bulb.
3. Liquid in which the thermometer is immersed.
4. Circulation of the medium.

It may be said also that the actuating liquid of the thermometer has considerable effect.

It is not the purpose of this article, however, to repeat the discussions of Harper. The reader should, if interested, refer to the original publication.

2. Principal Structural Causes of Lag

Fig. 1 shows the simplified construction of an Industrial thermometer. Often the metal bulb chamber is ensheathed in an additional metal covering known as a "separable socket." Such a socket, of necessity, introduces a lag, the discussion of which is also beyond the scope of this article.

The size and shape of the glass bulb are somewhat limited by practical considerations. A long slender bulb is usually more sensitive than a short thick one, as more surface per unit volume is available to absorb heat. The difference in the time between bulbs of various shapes is important where the bare bulb is used in direct contact with the liquid of the bath, but this difference is overshadowed by other factors when the bulb is surrounded by a metal chamber. The time lag is greatly increased when the heat necessary to raise the temperature of the bulb must first flow through the metal covering, then through a

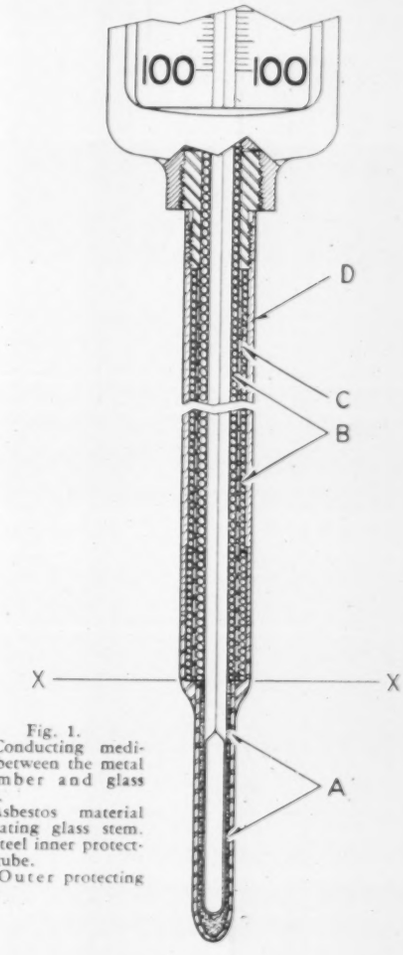

Fig. 1.
A—Conducting medium between the metal chamber and glass bulb.
B—Asbestos material insulating glass stem.
C—Steel inner protecting tube.
D—Outer protecting tube.

conducting medium ("A" in Fig. 1) and finally, through the glass wall of the bulb before it can raise the temperature of the actuating medium. Thus, a bare bulb may have a lag of three seconds, but when it is placed in a metal chamber the combined lag will be twenty seconds or more.

The material of which the metal bulb chamber is made is generally determined by conditions of use. Brass or copper may be used in some liquids; others require stainless steel; and some applications require pure silver. However, all metals are good conductors, and the time difference between silver and steel is slight. Obviously, the thickness of the chamber is of some importance, particularly where the thermometer is used in a material that cannot supply many calories quickly. Air or gas may be considered such a medium. Viscous oils, where the circulation is poor, may be cited as another example. Thickness of material of the stem is important for two reasons: (1) time is required for the heat to pass through the metal and (2) greater thickness means additional metal which must be heated.

*Article written for *Instruments* but incorporating the substance of a lecture at the Gibson Island Research Conference on Instrumentation of the American Association for the Advancement of Science, August 28, 1942.

[1] D. R. Harper, "Thermometric Time Lag," *Bulletin of the Bureau of Standards*, Vol. 8, 1912, pages 659-714. (Reprinted as *Scientific Paper No. 185*, 1912.)

By far the greater part of the lag is introduced by the conducting medium between the inside wall of the metal chamber and the glass wall of the bulb ("A" in Fig. 1). Obviously, this medium should be a good conductor of heat, and it is desirable also that its heat capacity be as low as possible. These two requirements are mutually incompatible. Good conductors are generally heavy and, in addition, have high specific heats.

In 1927, experiments were performed to determine, if possible, the most suitable material for this purpose. Several thermometers were made and the bulb chamber filled with mercury. Time-temperature response curves were obtained. Then, the same thermometers were packed in the same chambers, but with copper dust substituted for mercury. Again, their time-temperature curves were determined. Similar experiments were performed using graphite and copper oxide. Neither mercury nor graphite can be used at

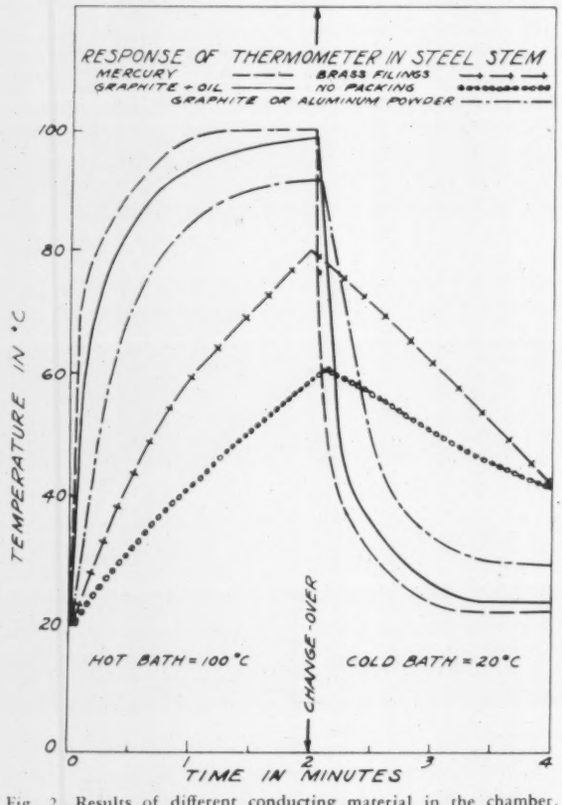

Fig. 2. Results of different conducting material in the chamber. (After R. P. Donnelly, *Chemistry and Industry*, April 1939.)

extremely high ranges, and it was thought that copper dust might turn into copper oxide with use. It will be seen that the above method eliminates error introduced by variations in the shapes of individual bulbs and chambers. Other workers have neglected these precautions and have used thermometers which appear to be similar in shape but may not be. For instance, thermometers may have bulbs of different wall thickness, and this difference may tend to vitiate any results so obtained.

Detailed discussions of some factors responsible for lag, as well as reports of test results and recommendations pertaining to various fields of temperature measurement, were published in the technical literature during the last fifteen years. The most detailed discussions seem to have been those in the aeronautic literature, the stimulus no doubt being the vital importance of minimizing errors in reading free-air temperatures during rapid climbs. Some of these reports[2-6] contain recommendations of value in connection

[2]H. B. Henrickson & W. B. Brombacher, "Lag of Thermometers and Thermographs for Aircraft." *Monthly Weather Review*, U.S. Weather Bureau, Vol. 55, Feb. 1927, pages 72-73.

[3]H. B. Henrickson, "Thermometric Lag of Aircraft Thermometers, Thermographs and Barographs." *Bureau of Standards Journal of Research*, Vol. 5, Sept. 1930, pages 695-709.

[4]C. Konig, (Indications of thermometers in moving air). *De Ingenieur* (Amsterdam), Report No. A332, 1932.

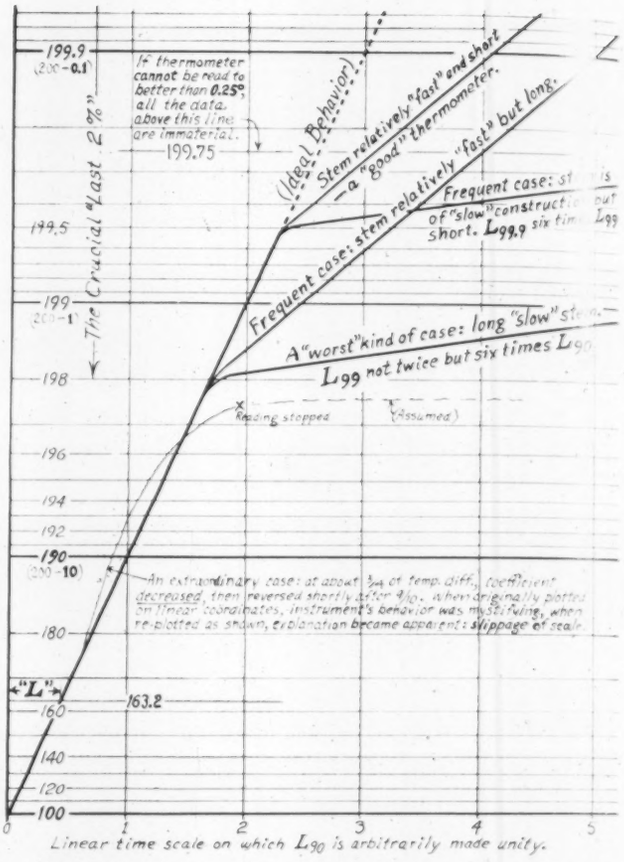

Fig. 3. "Semilog Plot Demonstrating the Newton-Harper Law and Departures Therefrom." (M. F. Behar, *Transactions A.S.M.E.*, August 1941.)

with measurements of industrial air and gas temperatures where the circulation is rapid.

In 1939, R. P. Donnelly[7] read a paper before the London section of the English Chemical Society describing experiments which he performed. Unfortunately, these experiments cannot be critically studied, as his complete paper has not been received. The results which he published are shown in Fig. 2.

At the December 1940 meeting of the American Society of Mechanical Engineers, R. Beck[8] presented a paper on "Thermometric Time Lag" reviewing Harper's work and emphasizing the importance of recognizing lag in the writing of specifications, but concluding with a proposal for Standard Specifications based on the Newton-Harper law:

> The time lag of the thermometer in (medium) at a uniform rate of temperature rise must not exceed () seconds.
>
> The time lag is to be determined by transferring bulb at temperature T_a into a (medium) bath at temperature T_b and measuring the time required for the indication to progress from T_a to $T_c = T - 0.368\ (T_b - T_a)$ with bulb at rest and bath stirred moderately. This figure will be accepted as representing the time lag in (medium) at a uniform rate of temperature rise.

3. Effect of Stem Lag Graphically Shown

Thus, up to fairly recently, discussions of thermometric lag published in the technical journals failed to distinguish stem lag from bulb lag. And yet, as we shall see, the importance of stem lag was not unknown—even though it was unpublished. The presentation of Beck's paper before an influential engineering society (and perhaps the danger of

[5]Vaclav Smolar. "Détermination de la Température de l'Air pendant les Essais en Vol." Aeronautical Research Institute, Prague, Czechoslovakia, Vol. 6, 1932, No. 18, page 37. (Abstract in French.)

[6]J. B. Peterson & S. H. J. Womack, "Electrical Thermometers for Aircraft," National Advisory Committee for Aeronautics Report No. 606, 1937. (16 pages.)

[7]*Chemistry and Industry* (London), Vol. 58, April 1, 1939, page 285.

[8]*Transactions A.S.M.E.*, Vol. 63, August 1941, pages 531-538.

tion of Standard Specifications as proposed therein) ap s to have been the stimulus which led M. F. Béhar to g this subject out into the open—which he did in di sing Beck's paper in 1941. The greater part of Béhar's di sion[9] is of interest to thermometer manufacturers ra r than users and hence need not be summarized here, bu s conclusion may be quoted at some length:

> *There is no such thing as a thermometer that obeys exactly the simple law* (the one formulated by Harper . . .) very actual thermometer is a composite structure, the components of which not only have different temperature coefficients of expansion or of resistance or of pressure, etc., but have also different time responses to changes in temperature. . . .
>
> It is to be regretted that the author worded the closing paragraph of his paper as he did. . . . Not only does the author fail to mention that this law [Newton-Harper] applies only to an ideally simple thermometer but his numerical examples, prepared for users of actual (hence relatively complex) thermometers, include figures which seldom apply to actual thermometers and which are "way off" for most instruments of obvious structural complexity . . . under most conditions of use. For instance, he gives the familiar 100-200 degree and $L = 10$-sec. example:
>
> Thermometer reading, °F.....100...190...199...199.9
> Time elapsed, seconds.....0....23...46....69
>
> as if it were true of all thermometers . . . The writer maintains the following:
>
> 1. The relation shown by the dominant line in Fig. 14 of this discussion [Fig. 3], which is simply a semilog plot of . . . the Newton-Harper law, is true only of an ideal thermometer in which only one element, say the mercury within the bulb, responds to temperature changes while all other elements remain unaffected by such changes.
>
> 2. The great majority of actual thermometers exhibit a composite lag (see secondary solid lines in [Fig. 3]).
>
> 3. In such cases the effect of secondary, tertiary and other lags is to make the approach to the asymptote slower than that predicted by the "simple law."
>
> 4. In many such cases the observer is deluded into thinking that the mercury or pointer has stopped before it has really stopped. Inevitable result, a wrong reading.
>
> 5. This error of reading is proportional to the difference between initial and final temperatures (other factors being equal). Therefore it is most serious in the use of testing thermometers which are taken from the pocket or hook or box at room temperature and immersed into the medium; examples: most laboratory thermometers and practically all "handled long stem" thermometers used in various food industries, in varnish-making, etc. . . .
>
> 6. The form of lag specification proposed by the author . . . should not be adopted as an American Standard, however useful it may be as an educational device for the benefit of purchasing agents and others to whom the whole subject of thermometric lag is a recondite subject. Where precision is imperative, determination of L_{90} and L_{99} (even if magnifying glasses or cathetometric telescopes are thereby necessitated) should be written into the specifications, and tolerances should preferably be expressed in terms of the difference of slopes on semilog paper.
>
> It is to be regretted in this connection that the author did not use logarithmic ordinates for any of his diagrams where temperatures are the ordinates. . . .
>
> It is on semilog plots that departures from exponential laws show up best; therefore semilog paper serves also as an excellent check on the accuracy of observations. Moreover, the semilog plot magnifies the really important region, i.e., the approach to the final reading of the instrument, which is nothing but a blur of merging lines on linear coördinates. Finally and most importantly, there is the . . . simplicity of representing different lag coefficients by straight lines of different slopes; hence, conversely, being able to discover the existence of different components of the actual curve of the instrument.
>
> The importance of this last-mentioned reason (straight lines) cannot be over-emphasized in connection with writing lag specifications, running acceptance tests, assigning "figures of merit" to competitive instruments, . . .
>
> In conclusion, a word as to how the four typical cases in [Fig. 3] happen to be so neat and parallel: the writer purposely drew them that way, to bring out the effects of short-fast, short-slow, long-fast and long-slow stems. This does not invalidate their actuality; they are truly "representative" cases, not hypothetical cases.

Donnelly's experiments with industrial thermometers cannot be re-plotted on semi-log coördinates to show the influence of stem lag because his points are not given in sufficient detail. The curves in Béhar's 1941 A.S.M.E. discussion were purposely plotted by him on semi-log coördinates to bring out in a vivid manner his classification of stem lags into four types; but he did not publish the four series of test points.

Fig. 4 shows typical results obtained by the writer. It will be noted that the points of the experimental data did not fall upon straight lines on semi-log plot, but were curves. Study of these curves indicates that the system does not follow the simple law, but that it may be composed of two or more parts, each with a different lag.

For a first approximation, the thermometer may be divided into two parts:— the first consisting of the bulb, bulb chamber, conducting medium, etc., the second consisting of the stem, i.e., the part between the bulb and the case containing the scale. Thus, the points of Fig. 4 roughly fit two straight lines, the steep portion being the action of

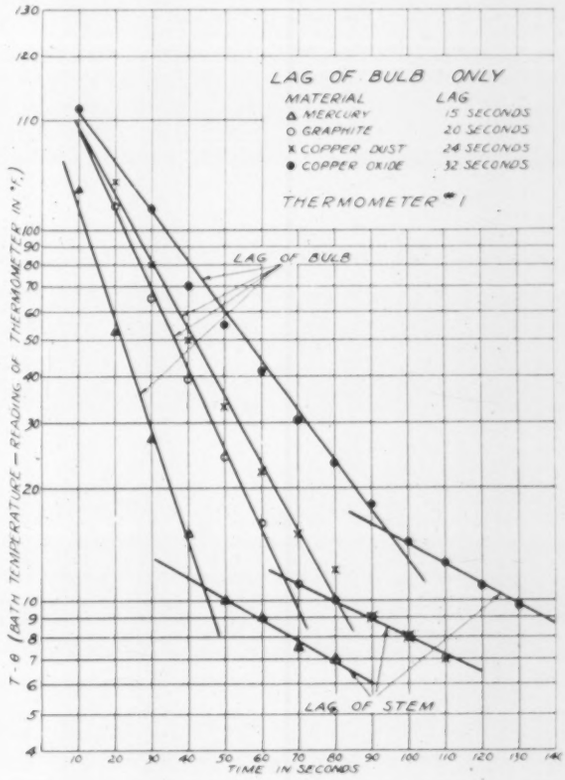

Fig. 4. Left curves show lag of same glass bulb, packed in same chamber, with different conducting media. Lower right lines show lag of stem.

the bulb which contains most, but not all, of the thermometric liquid, and the second or slower part, which contains a small fraction of the actuating liquid, in a much greater lagged container. It will be noted that the less steep straight lines are roughly parallel, showing that the lag of the stems is independent of the conducting medium packed around the true bulb—a result to be expected.

It was decided to divide the thermometer into two separate parts for study. The first part may be considered to consist of the bulb proper, together with the conducting medium and metal bulb chamber; that is, all of the thermometer below line XX, Fig. 1. This part of the thermometer was found to obey the theoretical equation closely, and the results shown by the steep lines in Fig. 4 represent conditions to a reasonable degree of accuracy. Aside from choosing the best conducting medium, there is little prospect of improving the speed of the instrument at this point. More often than not, this choice is determined by other factors, such as range, condition of use, etc.

The stem portion offered somewhat more promise. Fig. 5 shows the conventional method of construction of a typical

[9] *Transactions A.S.M.E.*, Vol. 63, August 1941, pages 539-540.

stem. In a short or in a cheap thermometer, the inner steel tubing is sometimes omitted. It was thought that if the asbestos could be omitted, the stem might act more quickly. With this in mind, steel support springs were substituted

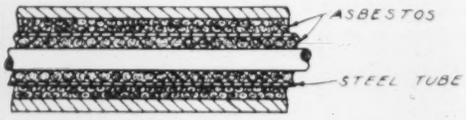

Fig. 5. Conventional method of supporting glass stem.

as shown in Fig. 6. Air became the conducting medium, although it was realized that it was a very poor conductor. Several thermometers were constructed in this manner, but the results obtained were not satisfactory. The differences in bulb lag from instrument to instrument were large enough to entirely vitiate the results.

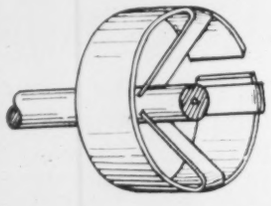

Fig. 6. Experimental method of supporting glass stem by steel springs.

4. Tests of Stem-like Bulbs Revealed the Important Factors

Thus, in order to measure the lag of the stem accurately, it became necessary to build some thermometers of somewhat unusual type. The general construction was that of the well-known "Faden thermometer." The glass instrument consisted of a bulb with about the same external diameter as that of the glass used in the stem of an industrial instrument. Various lengths of bulbs were made as well as various diameters. The capillary bore of the bulb was slightly larger than the capillary usually used in the usual stem. To the top of those bulbs was joined a piece of glass having an exceedingly fine capillary. The large stem glass then became the bulb, and the scale was engraved on the fine piece of capillary. These thermometers were mounted in metal stems, supported or packed in various ways, so that only the top piece with the scale projecting from the bath was in view.

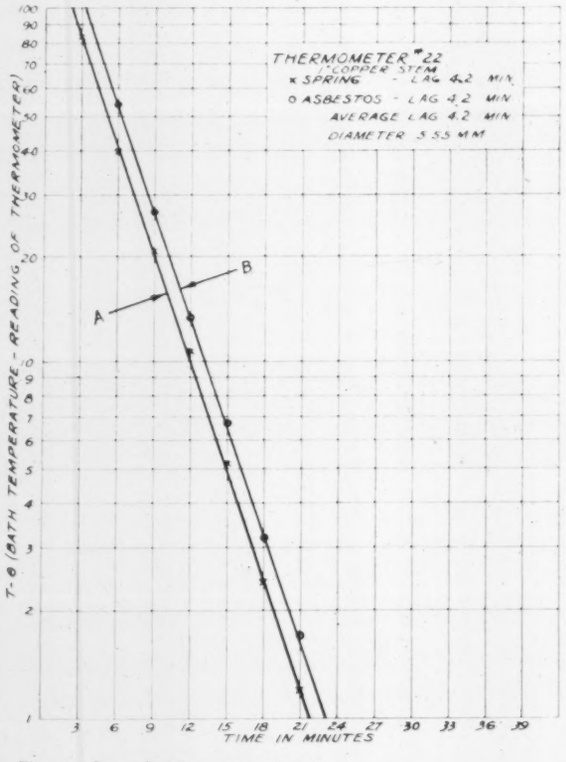

Fig. 7. Lag of thermometer (stem)—
(A) supported by steel spring.
(B) packed in asbestos in conventional manner.

Thermometers made as described above were plunged into hot liquids, and the time-temperature relations determined. The thermometers were then disassembled and mounted in tubes of different metals, or supported in a different manner with different materials between the glass and metal.

In Fig. 7 are plotted data which show (1) that such a thermometer obeys the Newton-Harper law and (2) that there is no appreciable difference between the speed of response of a thermometer packed with asbestos in the usual manner and the speed of one mounted in a steel spring. Thus, it is shown that under these conditions, the air is as ineffective an insulator as is asbestos. Fig. 7 shows that for a bulb 5.55 mm. in diameter, the lag L is 4.2 minutes. Similar studies with tubes of different diameter show that the lag increases with the diameter of the glass. For instance, a bulb 6.85 mm. in diameter shows a lag of 5.6 minutes. This effect is due to two factors: (a) the additional heat required to warm the extra glass and (b) additional glass which the heat must pass through to reach the mercury.

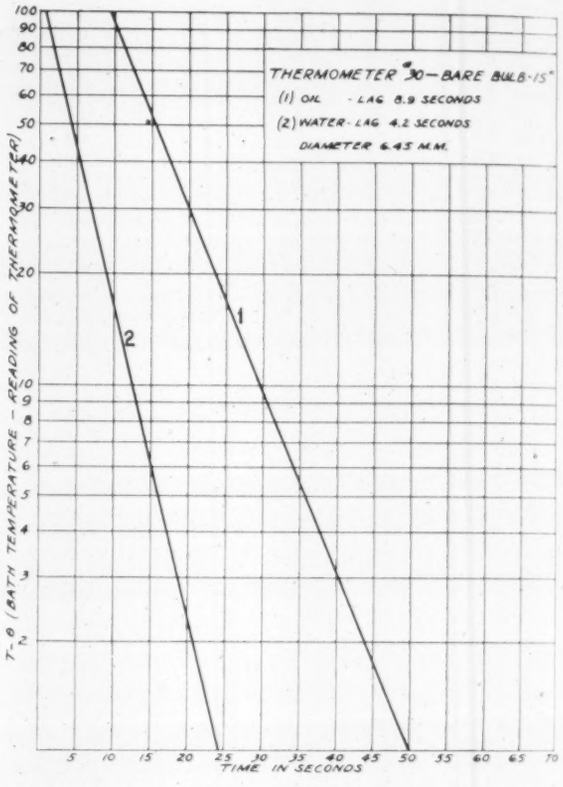

Fig. 8. Lag of bulb made of thick stem capillary—
(1) in oil. $L = 8.9$ sec.
(2) in water, $L = 4.2$ sec.

Even though Harper had performed somewhat similar experiments, it seemed worth while to see how different immersion media would affect an extremely thick-walled bulb such as was being used. Fig. 8 shows such data. It will be observed that the lag in oil is slightly more than twice that in water, even though the oil was well circulated. Other data proved that smaller diameter tubes showed less lag, as would be expected.

Without giving the experimental results in detail, it may be said that the material of the metal sheath made little difference. All metals are relatively good conductors, and the difference in lag between copper and steel tubing was extremely small when compared with the lag of the material between the metal tubing and glass bulb and with

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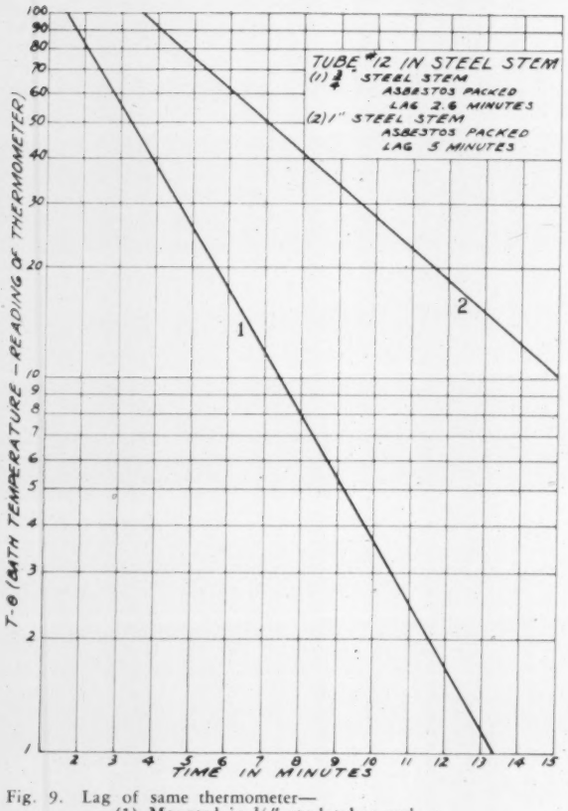

Fig. 9. Lag of same thermometer—
(1) Mounted in ¾" steel tube; and
(2) Mounted in 1" steel tubes.
Packed in conventional manner in each case.

the lag of the thick-walled bulb itself. Nor did length of stem affect the actual lag of the stem, although it will be reaized in the later discussion, that the total lag of the thermometer will be decidedly affected by the stem length or, rather, by the number of degrees represented by the volume of the capillary in the stem.

It is commercial practice to make some thermometers of 1" tubing, others of ¾" tubing. The 1" thermometers at least cost more than those made of ¾" tube. There are of course, some factors in favor of the larger tube, as one would expect, but insofar as lag alone is considered, a ¾" tube is better. For instance Fig. 9 shows the same thermometer packed in a 1" tube and in a ¾" tube. The lag with the large tube is almost twice that of the smaller tube. The same results were obtained with brass and stainless steel stems.

It appeared that if a good conducting medium could be used instead of asbestos or air, the lag might be considerably decreased. Such a material must, of course, give support to the tube and, at the same time, have low specific gravity. It should also be stable at reasonably high temperatures. Graphite, alone, seemed to meet these requirements; and experiments were continued with it substituted for the asbestos and air previously used.

The lag of a stem thus packed was found to be only about one-half of the lag of a similar stem packed in the usual manner. Figs. 10 and 11 give curves for a thermometer packed in three different ways. It is clear from these and other curves that the lag of the stem can be halved by reducing the diameters from 1" to ¾". The lag can be halved again by using graphite instead of asbestos as a packing material. Thus the lag of the stem of a 1" thermometer may be cut to 25% of its original value by reducing the stem diameter from 1" to ¾" and substituting graphite for asbestos.

5. Predicting Stem Lag

Having obtained these experimental results, it is possible to determine in advance the lag of a given thermometer with considerable accuracy. Let us take, for example, a thermometer often used in commercial candy making: The stem is customarily about 3 feet long, the range from 200°F. to about 400°F. If the maker has used good judgment, the glass in the stem has been so chosen that the

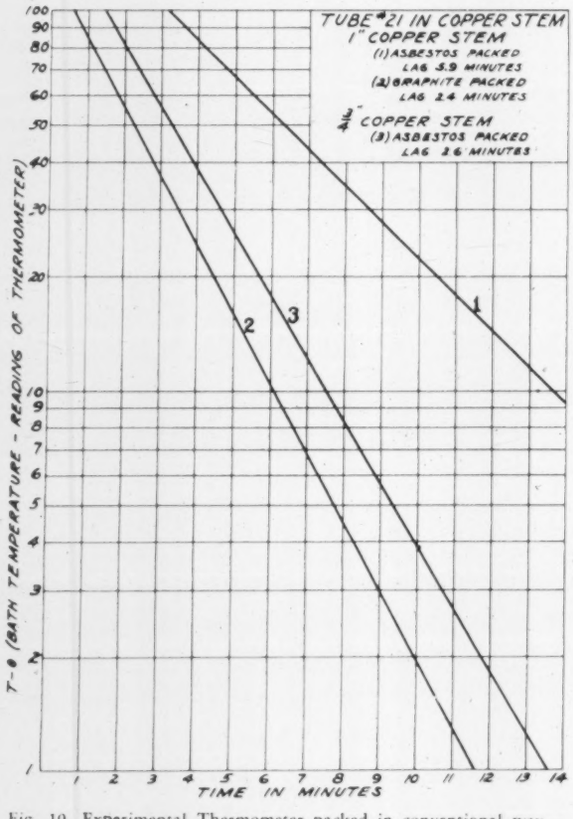

Fig. 10. Experimental Thermometer packed in conventional way—
(1) 1" copper stem—lag 5.9 min.
(2) Same stem—graphite substituted for asbestos—lag 2.4 min.
(3) Packed in ¾" stem, asbestos material—lag 2.6 min.

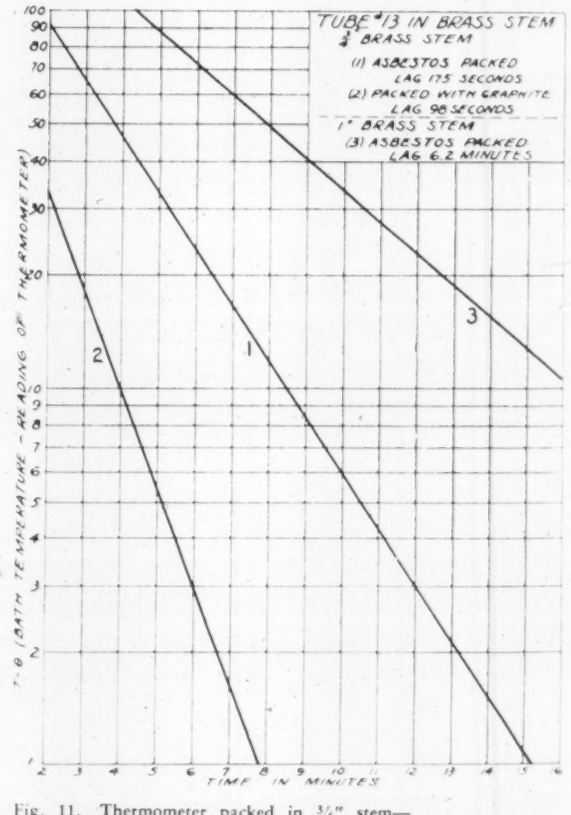

Fig. 11. Thermometer packed in ¾" stem—
(1) Asbestos packing, lag 2.9 min.
(2) Graphite substituted for asbestos, lag 98 sec.
(3) Packed in asbestos—1" tubing—lag. 6.2 min.

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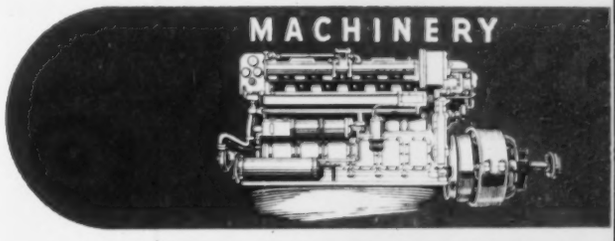

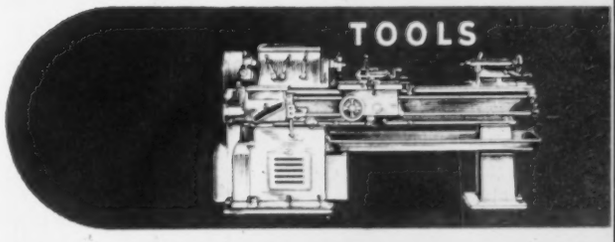

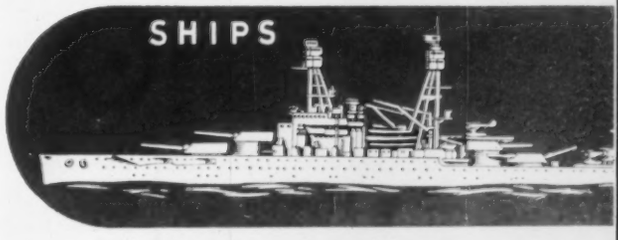

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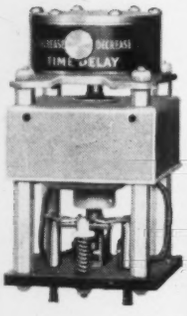

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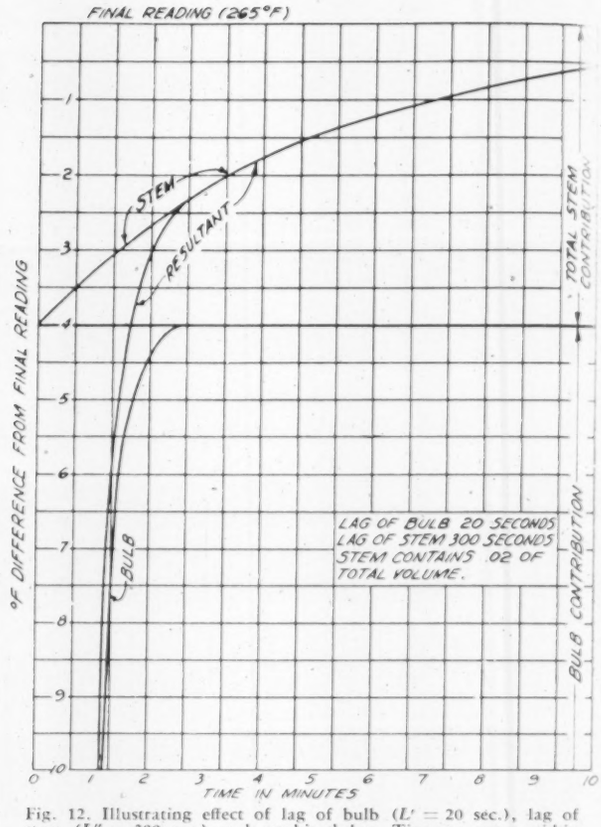

Fig. 12. Illustrating effect of lag of bulb ($L' = 20$ sec.), lag of stem ($L'' = 300$ sec.) and combined lag. Time to come within $1^\circ = 7$ min.

mercury will not recede into the bulb at 0°F. in order that air will not get into the bulb during shipment. The thermometer may be used at any temperature on the scale, but a temperature of 265° will be assumed. About 200 degrees

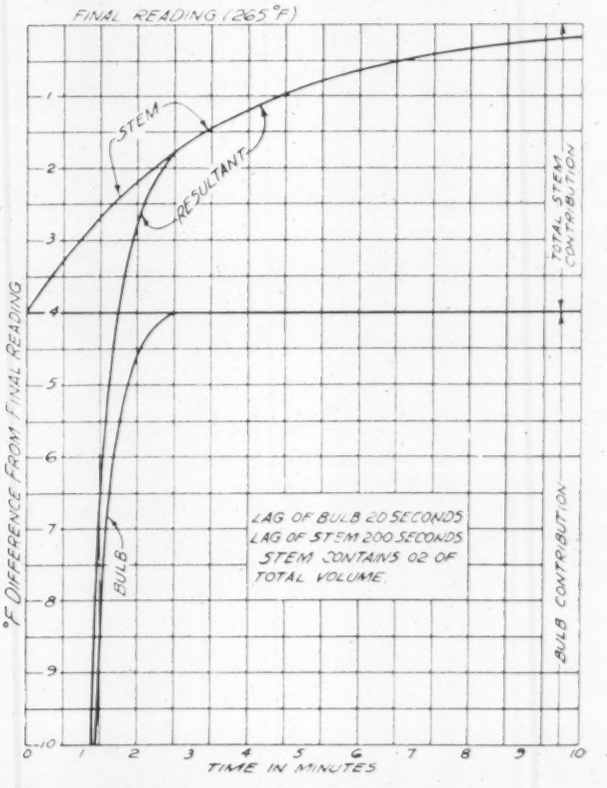

Fig. 13. Same bulb as in Fig. 10 ($L' = 20$). Stem quicker ($L'' = 200$). Time to come within $1^\circ = 4\frac{1}{2}$ min.

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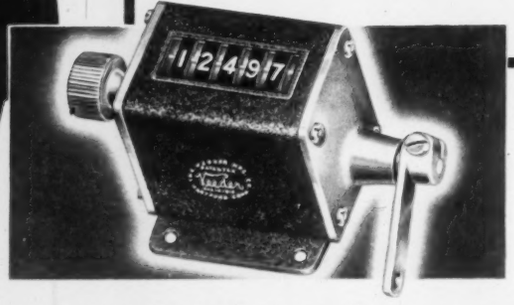

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will [illegible] in the stem (i.e. from 0 to 200, the bottom of the sca[illegible] and since the apparent expansion of mercury in gla[illegible] is about 0.0001,[10] about 200/10,000 or 2% of the tot[illegible] volume of mercury will be in the stem when the instr[illegible]ent is being used.

E[illegible]uation (1) no longer represents the action of the thermo[illegible]ter. Instead, a second term must be introduced to take car[illegible] of the stem lag. This equation now becomes:

$$(\theta-\omega)/(\theta_0-\omega) = (1-f)e^{-(1/L')t} + f^{-(1/L'')t} \quad . \quad (2)$$

wh[illegible] "f" represents the fractional part actuating liquid co[illegible]tained in the stem. L' is the lag of the bulb and L'' is the lag of the stem. In the illustration chosen "f" is 0.02.

Fig. 12 shows the effect of bulb lag and of stem lag, as well as the total lag caused by both factors. Here the thermometer is plunged into a liquid at 265° F. The stem lag is 300 seconds. The bulb comes up to temperature in about 2½ minutes; the stem takes much longer. Although

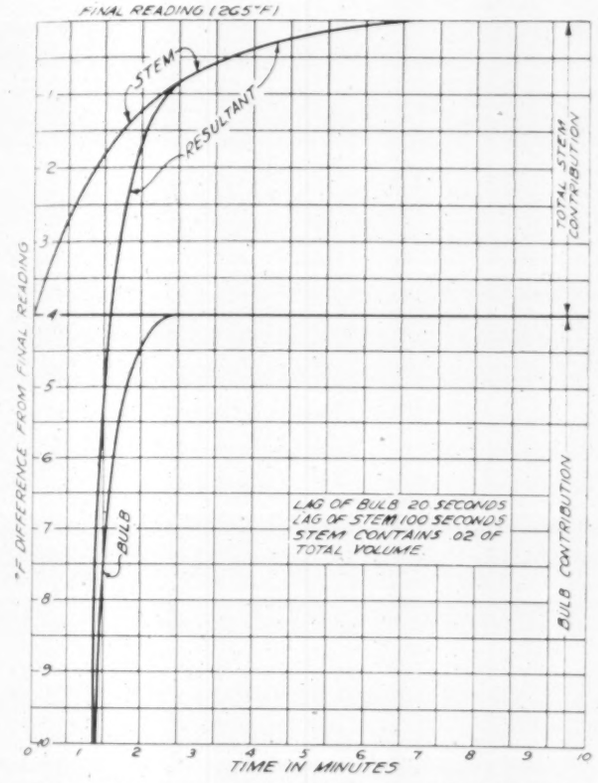


Fig. 14. Best stem L''. ($L' = 20$, $L'' = 100$ sec.). Thermometer comes to within 1° in 2.7 min.

the volume of the stem is only 2% of the total volume, it nevertheless retards the action of the entire thermometer. Thus, it takes seven minutes for the instrument to read within 1° of the true temperature (L_{99}).

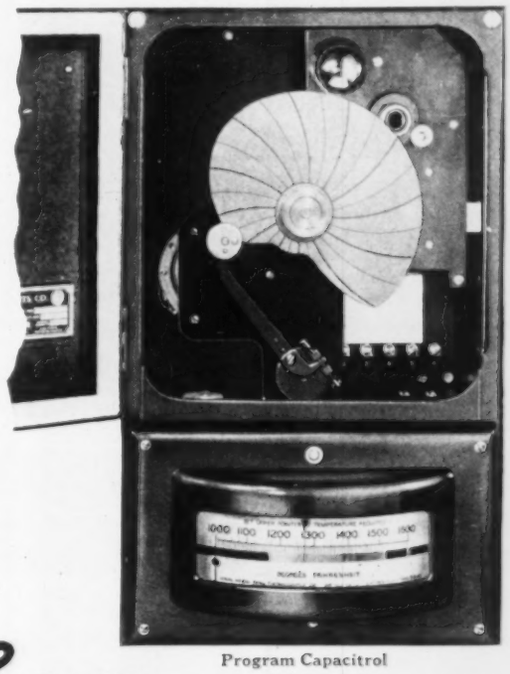
Suppose a thermometer be considered in which the stem lag is reduced to 200 seconds (such a reduction could easily be secured by reducing the stem diameter from 1" to ¾" or by packing the larger stem with graphite). Fig. 13 shows that the lag L_{99} is now only four and one half minutes instead of seven minutes.

The final step is to use the minimum practical lag of stem, about 100 seconds. This represents a ¾" tube, packed with graphite. Here, as in Fig. 14, the lag L_{99} is reduced to less than three minutes.

The above figures also indicate the fallacy of trying to compare instruments by measuring the time necessary to reach L_{90} or 90% of reading. Each of these figures shows that it would only require about one minute for any of the thermometers to come to within 10° of the correct reading, or about 95% of the change. Nevertheless, these thermom-

(Continued on page 492)

[10] 0.000089 in Corning Normal Glass.



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3. The Lease-Lend Plan of the A.A.S.W.

AMERICAN ASSOCIATION OF SCIENTIFIC WORKERS
NEW YORK BRANCH
28 Washington Square N., New York, N. Y.

September, 1942

"LEND-LEASE" OF SCIENTIFIC APPARATUS

Many laboratories are finding it impossible, at the present time, to purchase apparatus necessary for their research work. Since most instruments are now being produced almost exclusively for the armed forces, laboratories are faced with a very serious limitation of their research programs.

To alleviate the problem of apparatus shortage, the New York Branch of the American Association of Scientific Workers is attempting to set up a project for "lend-lease" of scientific equipment as a contribution to the war effort. The plan embraces the following objectives:

1. The compilation of a registry of scientific apparatus possessed by various industrial, research and university laboratories in this region and which is available for loan, lease and sale.
2. The determination, by a questionnaire, of apparatus which laboratories would be willing to lend, lease or sell to other laboratories requiring this apparatus.
3. The establishment of a central clearing office through which the laboratory requiring apparatus could contact the laboratory willing to lend, lease or sell same. Inquiries for apparatus could then be made through this office. The laboratory owning apparatus is in no way obligated and will be the sole party to determine whether and under what terms any equipment is to be made available in each case.

In order to set this project in motion with the utmost speed, we are respectfully requesting your coöperation in answering the attached questionnaire. We trust that we may be of service to you in locating "unavailable" apparatus.

WAR EFFORTS COMMITTEE

QUESTIONNAIRE L—Lend-Lease of Scientific Apparatus

Research Laboratories: Industrial, Institution, University

This list is intended to indicate the types of unavailable apparatus. It is intended to be suggestive rather than exhaustive. Please feel free to extend or modify this list to meet your needs.

1. Name and address of Laboratory:
2. Name and title of person filling out this questionnaire:
3. Name and title of person in your laboratory whose permission must be secured in order to arrange loan, lease or sale of apparatus:
4. Would your instrument and machine shop undertake the construction of special apparatus for research purposes, satisfactory remuneration having been agreed upon? Specify the types of special work which your shop is equipped to undertake.
5. Would competent mechanics be permitted to use your machine shops for repair and construction of research apparatus, when the shops are available?
6. Certain apparatus (e.g. X-Ray outfit, Mass Spectrograph, etc.) cannot be loaned because of its stationary character. Would qualified workers be permitted to use such apparatus in your laboratory, when not otherwise in use?
7. Comments:

[Below are the listings in the first column only of the mimeographed form. The other columns are blank; they are headed *"Type," "We Need"* and *"We Have."* Interested readers of *Instruments* should send for the form itself.—EDITOR.]

Ammeters
Amplifiers
Autoclaves
Bridges, special:
  Wheatstone
  Mueller
  A.c.
  Capacitance
  Kelvin
  Conductance
Cages
Calculating machines
Calorimeters
Cathode-ray oscillographs
Centrifuges
Colorimeters:
  Visual
  Photoelectric
Constant-temperature apparatus
Decade resistance boxes
Diathermy apparatus
Efficient fractionation stills
Electric motors
Electrophoresis apparatus
Filters
Galvanometers
Geiger counters
High-pressure apparatus
High-speed photographic equipment
High-temperature apparatus
Hydrogenators
Interferometers
Kymographs
Lamps, special:
  Sodium
  Ultraviolet
Lenses
Liquid air, nitrogen, hydrogen
Low-temperature apparatus
Low-temperature baths
Machine tools, precision:
  Lathes
  Grinders
Magnetic susceptibility apparatus
Mass spectrographs
Metal sputtering & evaporating equipment
Microchemical:
  Balances
  C-H outfit
  N outfit
Microdissectors
Micromanipulators
Micrometers
Microphotometers
Microscopes:
  High-power
  Polarizing
  Reflecting
Microscope accessories
Microtomes
Muffle furnaces
Nephelometers
Optical pyrometers
Oscillators
Ovens
Photomicrographs
Polarimeters
Polarographs
Potentiometers
Power supply units
Pressure chambers
pH meters
Radioactive sources
Radiometers
Resistance thermometers
Refractometers
Rheostats
Shakers
Short-wave apparatus
Spectrographs
Spectrophotometers
Stimulators
Stopwatches
Stroboscopes
Supersonic apparatus
Timers
Thermocouples
Ultracentrifuges
Ultrafilters
Vacuum pumps
Vacuum-tube voltmeters
Van Slyke apparatus
Voltmeters
Warburg-Barcroft apparatus
X-Ray apparatus

Others (to be filled in on Questionnaire "L")

AMERICAN ASSOCIATION OF SCIENTIFIC WORKERS
NEW YORK BRANCH
28 Washington Square N., New York, N. Y.

September, 1942

"LEND-LEASE" OF SCIENTIFIC APPARATUS

We are enclosing copy of Questionnaire L which the New York Branch of the American Association of Scientific Workers is presenting to laboratories in conjunction with a "Lend-Lease" plan for scientific apparatus which is unavailable in the present emergency.

In order to carry out this project most efficiently, we would welcome the cooperation of the manufacturers, dealers and supply houses which ordinarily handle such apparatus.

We have, therefore, prepared a special Questionnaire S for the suppliers of equipment. Your answers to this questionnaire will be of inestimable assistance to our Committee in carrying out this project.

May we count upon your cooperation?

WAR EFFORTS COMMITTEE

QUESTIONNAIRE S—Lend-Lease of Scientific Apparatus

Manufacturers, Dealers, Supply Houses of Apparatus

1. Name and address of firm:
2. Name and title of person filling out this Questionnaire:
3. Do you think there is need for a "lend-lease" of instruments and apparatus for research laboratories during the present emergency?
4. If such a plan were adopted, would your firm cooperate by informing laboratories seeking special, otherwise unobtainable, equipment of the existence of such a plan?
5. Is your firm able, at the present time, to make repairs upon instruments and apparatus?
6. Please check in Questionnaire L, in column headed "We Need" those items which are at present unavailable, and in column headed "We Have" those items in stock and still available to research laboratories.
7. Comments:

For the Government-approved plan of the Instruments Publishing Co., see October *Instruments*, page 396.

For the plan of the Committee on Location of New and Rare Instruments, see August *Instruments*, page 326.

Why Automatic Controllers May Behave Like Human Beings—The Modes of Control

By M. F. BEHAR

FIRST of all, is the above title an illegitimate attention-attractor? Is it conceivable that a man-made thing—even the most highly perfected robot—can *behave*, as a human being behaves? How can it, if it is *automatic*? According to John B. Watson, who taught psychology at Johns Hopkins University and made "behaviorism" into a science:

> The behaviorist takes the position at the outset that the total behavior of man from infancy to death is the subject-matter of (human) psychology. Behavior can be observed like the phenomena of all other natural sciences; e.g., chemistry, physics, physiology or biology. The same general types of methods used in the natural sciences can be used in behavior psychology. So far in his objective study of man no behaviorist has observed anything that he can call consciousness, sensation, perception, imagery or will. Not finding these so-called mental processes in his observations, he has reached the conclusion that all such terms can be dropped out of the description of man's activity.*
>
> What has the behaviorist to offer on thinking? The behaviorist's formulation runs somewhat as follows:—
>
> The increasing dominance of language habits in the behavior of the developing child leads naturally over into the behaviorist's conception of thinking. The behaviorist makes no mystery of thinking. He holds that thinking is behavior, is motor organization, just like tennis playing or golf or any other form of muscular activity. But what kind of muscular activity? The muscular activity that he uses in talking. Thinking is merely talking, but talking with concealed musculature.†

Thus the difference between the simple automatic response of a limit switch, for example, and the incomprehensibly complex "automatism" of a living organism endowed with thought, would seem to be only a difference of degree—not of mutually-exclusive categories.

In 1928, a study of a newly-developed automatic controller, as well as the need of describing the infinitely numerous gradations of "control action" which it was capable of displaying at the will of the user, led to a search for a new term. The specific need was to convey to the mind of the reader of the description that he (as a user) should think of this controller as more than a simple cause-and-effect device—as more than a dead thing.

Such expressions as "on-and-off," "proportioning," "throttling," etc., then in vogue, all referred to kinds of controllers. (And many new terms of this nature still refer to types of controllers—types of construction.)

In order to focus attention on the subject of behavior alone—on the quality or grade or kind of behavior, and specifically on this behavior as the performance of an assigned job—the expression "mode of control" was coined.

This approach to the general subject of automatic-control technology (or to merely one phase of this general subject—the distinction is immaterial) being new and radically different from any other approach, it was elaborated in various writings, lectures, etc.

Thanks largely to the appearance of these writings in publications issued by the Instruments Publishing Company in 1930-32, this approach began to take hold, particularly in the oil and chemical industries, as well as among the designers of automatic-control systems. On the whole, it has been fruitful. Chief objection to it, of course, is that it creates the desire to obtain "intelligent" modes of control which even the most highly perfected man-made things cannot display. The seriousness of this objection is not denied but, after all, "dissatisfaction creates progress" and "necessity is the mother of invention." Moreover, this behavioristic approach has enabled some of its devotees in industry to "teach new tricks" to their automatic controllers on some urgent occasions.

Every publication containing the dissertations on Modes of Control is out of print. In fact, none has been available since early in 1941. The writer had been at work on revisions (sorely needed because of the appearance of greatly improved automatic controllers on the American market), but his duties in connection with the Defense Effort—and since Dec. 7 the War Effort—have slowed down the progress of these revisions. To meet the demand as best we can, therefore, extracts from the original articles and books are reprinted without any alterations other than correcting minor slips not caught at the time.

Another purpose in reprinting these extracts here is to bring this method of approach to the attention of *Instruments* readers who are unacquainted with it. The great majority of the 8200 present subscribers have not read the serials and books issued between 1930 and 1932. To them the extracts will be as new as the other articles published in *Instruments*. And many of the present subscribers who were subscribers in 1930-32 will probably have forgotten the original disclosures (which were far from earth-shaking, as the author cheerfully admits!).

Still another reason for reprinting these extracts is to prevent misunderstandings and confusion: The expression "mode of control" has lately been used by certain writers to denote a type of controller or an arrangement of the parts of a controller, or an application (in the purely physical meaning of a "processing equipment" or "method" or "process.") This is a free country and no one will stop any author from referring to a mechanism as a mode of control and from writing, (for example):—

> ". . . more complicated modes of control which might be built if seriously needed."

but when an author attributes the wrong meaning to me, as in the following:

> ". . . Strictly, 'process' means *'method'* rather than apparatus for carrying out a method. Sometimes *'mode'* is used to mean 'method' or process. (Behar)"

and when this appears not as a casual remark in a discussion of controllers or of processes or of control theory—but *in the section entitled "Terminology"* of an excellent book on control by an excellent author, then it would seem that the years since 1932 should not have been allowed to pass without the publication of more articles and books reiterating and re-presenting and elaborating the concept of the modes of control. Some authors have included brief presentations of this approach in their writings in the last few years (and they are to be commended) but although *they* undoubtedly had grasped the idea, it is evident that some of their readers did not. (Never has it happened that all readers of a technical discussion obtained identical impressions on all points.) So here are the extracts:

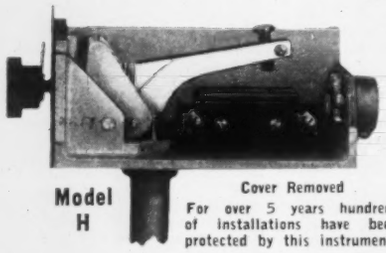
> Extracts from the first detailed disclosure, as it appeared in *Instruments*, Vol. III, 1930, pages 431 and 434. (The discussion of Modes starts on page 431 and ends on page 440. The complete instalment, "Automatic Temperature Control," runs from page 425 to page 462.):—

MAINTAINING the optimum temperature is not a case of balancing static forces. In any temperature apparatus we have an incessant flow and transfer of heat. The "driving" comparison throws much light on the subject: When you wish to maintain a speed of exactly 40 m.p.h., you keep your eye on the speedometer and expertly bear down on the accelerator. When you climb a grade, you have to increase the flow of mixture through the manifold; and on a downhill you sometimes can coast with the throttle almost shut. No matter how keen your eyesight or how quick your foot muscles, a recording speedometer would show a slightly sawtooth record. *You act only when there is a departure from normality.* You never can maintain a speed of exactly 40 m.p.h. but you can, depending on the degree of your skill, maintain 40±0.2 m.p.h., or 40±0.6 m.p.h. In like manner no controller can hold at the exact optimum temperature. It can only hold "within" so

*Encyclopaedia Britannica, fourteenth edition, Vol. 3, page 328.
†Ibid, page 329.

TEMPERATURE LIMIT SWITCHES

0 to 1400° F.



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many degrees, as the expression goes. What is called perfect control is close control.

Here ends the car driving comparison familiar to many engineers. Let us continue it: When you come to a hill you "step on 'er all the way to the foot-board." This is something which most classes of automatic temperature controllers *cannot* do and in fact are not designed to do. A sudden extraordinary increase in the demand is *not* automatically met with a corresponding sudden and extraordinary increase in the controlled supply. All but a few (and rather elaborate) classes of temperature controllers are inherently and designedly incapable of meeting *both* small and large variations in demand. And when we say controllers we mean the assembled elements of control systems. *Each* element has its own operating characteristics—chiefly *amplitude* characteristics and *time* characteristics. All of these together make up the "behavior" of one control system. The study of temperature control is primarily a study of the behavior of various control systems—the study of the various *kinds of behavior*.

This subject, by the way, far from being theoretical, is the most practical of all for the practical man to acquire. Just as in selecting men for jobs, not the height and weight but certain qualifications must be kept in mind, so in the application of temperature control, the study of various classes and makes of temperature controllers with reference to their appearance and construction is of little value to the engineer who lacks a clear idea of *performance standards*. For this purpose we have had to coin the expression "Modes of Control" because the familiar expression "operating characteristics" is inadequate: it refers to definite effects of given causes. "Mode of Control" has reference to The One Best Way of maintaining The One Best Temperature—*how* various controllers do it; hence how one does it better than another; hence how to select the most suitable.

Inasmuch as the subject at hand is essentially one of behavior, it will greatly simplify matters to personalize the controller. Instead of an instrument or elaborate system, let us have a *man* (as before the application of automatic control) and let us study his behavior under various circumstances—in a number of "cases," which are sometimes typical and sometimes merely of interest in bringing out various points. Indeed, let the reader take the part. Throughout this discussion *you* are the automatic controller. The mode of control in each case is not so much what you do as how you do it. . . .

Extracts from Chapter III of "Fundamentals of Instrumentation," (a book published in 1932):—

. . . These *control characteristics* largely determine the suitability of a controller for a particular control application. But in Sections 4 and 5 it was shown that the performance of a controller depends *also* on controller period and application lag; and that each of these factors is frequently a variable.

Therefore, the actual performance of a controller is determined not only by its ratio characteristics but by other factors. The number of possible combinations is infinite and the analogy of a controller to a human being comes to mind. A man has a given height and weight and he possesses a certain amount of strength and endurance, but these characteristics are not alone in determining his behavior in the face of a given set of conditions. Of a thousand men with the same principal characteristics, no two will act just alike. Similarly, the "performance behavior" of a controller, which we term its *mode of control*, is determined not only by its range, differential setting, etc., but by other factors, both inherent and external. Of a thousand auxiliary-powered controllers of a certain type, having exactly the same principal *characteristics*, no two will give exactly the same *mode* of control when they are originally installed.

This does not imply that any of these controllers, when originally installed, will *fail* to control. The controllers may all perform satisfactorily from the start. But they will perform differently on the thousand applications because they are not absolutely alike and the applications are likewise different if only in imperceptible respects.

Every piece of operative equipment has certain operating characteristics, some inhering in the class and type to which it belongs, others in the individual mechanism. An automatic control installation is an assembly of pieces of equipment—some operative and some passive—all of which together determine the resultant behavior of the controller under any given set of circumstances. This resultant behavior, as regards the controlled apparatus and condition, is the mode of control, and differs from what is usually implied by "operating characteristics."

A particular mode of control is the combined effect of a particular set of distinct characteristics, including application factors. Change any one characteristic or factor, and you change the mode. A control mode, then, is not a method but an actual behavior—a manner. The driving comparison suggests itself: you have a certain general way of driving cars which is peculiar to you, but it changes—if only slightly—whenever you take the wheel of a new car. Again, no two horsemen ride the same way, and one rider's style changes when he changes horses.

GRADES OF MODES

For evaluating modes of control, the expression "almost human," oft-seen applied to mechanisms, furnishes one basis—that of comparative "intelligence"—on which basis there is an indefinite number of possible modes—not sharply classified, however, but merely graded into an infinite series.

Neither the lower nor the upper limit can be sharply drawn. Below one extreme we must place, for example, the action of limit switches, trip arms and other such automatic devices not classed as instruments. Such action is not even a "characteristic" as usually defined.

Above the other extreme is the *judicious anticipation* of changes in demand, of which an example is shifting gears on *seeing* a steep grade just ahead, before the engine or an instrument applied to its control can respond to changes in inclination of vehicle—which mode of control can only be achieved at present by a rational and perspicacious agency

—human being of adequate physical and mental equipment.

While the lower and upper grade limits of the modes of control cannot be fixed definitely for industrial automatic controllers in general, it may be useful to select *one controllable condition* and define the practical and logical limits of the grade scale for this one condition.

Selecting one of the simplest industrial processing conditions, *liquid level*, we may fix the lower grade limit at the mode of control exhibited by a float valve—a device which resembles a limit switch but gives "tapering" or "throttling" instead of "on-and-off" control:

The supply valve is wide open when the float lever is at a certain angle below the horizontal; dead shut when the float lever is so many degrees above horizontal. *To every position of the float corresponds a definite valve opening.* . . . This throttling mode certainly is of higher grade than the action of a limit switch. It is true that most forms of float valves, such as those in sanitary fixtures, cannot be classed as industrial instruments—any more than can limit switches—but some automatic liquid level control instruments rendering satisfactory service on industrial applications operate on the same float principle and give modes of control of no higher grade.

The upper grade limit of the modes of liquid level control—as with automatic control in general—is set by the state of the art. Narrowing down the field still more, we now consider only the automatic control of water level in water-tube *boiler drums:*

[There follows a statement of the problem and an analysis of the Bailey three-element controller brought out late in 1931.]

Note that some modes of control made possible by this new system include the *anticipation* of changes in water level, by making the extent of corrective action depend more on changes in steam flow and less on changes in the level itself.

Summarizing as to grades: Below the grade of performance that can properly be called automatic control is the action of mechanisms. The lower-grade modes of control are single characteristics or rigid relations between change in condition and corrective action. . . . Discrimination characterizes the higher-grade modes. The ideal mode of control may be defined as the intelligent anticipation of all changes in demand. It probably will always remain an ideal, but—as just shown in the case of boiler drum water level control—modern control systems can and do really anticipate some changes in demand. Disregarding niceties of language, we may assert that the ideal mode of control is unattainable but perfect modes are here.

CLASSES OF MODES

Although indefinite in number of grades merging each into the next, the modes of control may be divided systematically into a somewhat arbitrary but always *definite number of mutually-exclusive classes.*

These distinct classes of modes do not make an ascending order as do the grades, since the question of relative merit does not enter in a general way. For example a class of modes excellently suited to the control of gas pressure might be unsuitable for regulating water pressure, water being practically incompressible and gases almost perfectly elastic. Nevertheless, the list naturally starts with three or four classes of "on-and-off" modes that are "actions" or "characteristics," and conveniently progresses upward.

There appear to be at present (1932) some twenty-five to thirty different kinds of controller performance behavior—each a distinct class of modes—but the current developments in photoelectric and other electronic control elements, and also in controllability of industrial processing equipment, will soon compel lengthening the list by the addition of new modes heretofore impossible of practical attainment. A *comprehensive* list of classes of modes must of necessity take in the applications and would be out of place in this chapter on controllers. If, however, we select the control of *one* condition on *one* application, it becomes possible to describe some classes of modes.

[The descriptions of 28 different classes of modes, which follows in the book, will appear in an early issue.]

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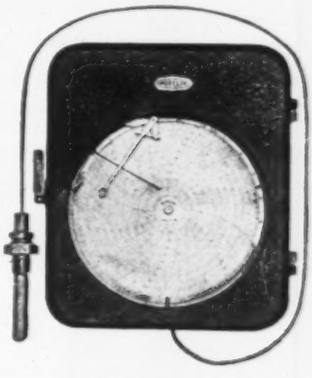

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Vol. I, No. 6 GUEST EDITOR: J. C. BANKS November 1942

Importance of Electrical Aircraft Instruments in War and Peace

Editorial by **JOHN C. BANKS**, *Guest Editor*

Chief Instructor of Electrical Dep't and Instructor-in-charge of U. S. Army Signal Corps Students, N. Y. School of Aircraft Instruments.

WHILE all kinds of instruments play important parts in aircraft control, the use of electrical instruments is increasing continually. One reason is the ease of transmission from the point of measurement to the point of reading, with nothing but one or more small wires to connect the two positions. Distances of transmission may be relatively long.

Aviation instruments may be divided into two general divisions: those operated mechanically, and those operated electrically. The second group may be separated again into two sections: first, those measuring electrical magnitudes such as voltage or current and, second, those using electricity as a means to an end. The first group are the voltmeters and ammeters used in the generator-battery circuit, and the second group includes such instruments as the electric tachometer, heat measuring devices such as thermocouple and resistance bulb thermometer, oil pressure gages, etc.

Some electrical instruments (group two) operate on the aircraft battery, others operate on power generated in the transmitter such as the tachometer and thermocouple. "Autosyn" type instruments operate on alternating current derived from a generator unit attached to the aircraft engine. The transmitters include the direct or alternating current for electric tachometers, which vary the voltage or frequency with the speed to be measured; the thermocouple which generates a voltage in proportion to the temperature; the resistance bulb varying its resistance with the temperature; the oil pressure on a Bourdon tube which actuates a variable resistance; a float operating the same, etc.

Although they are rugged (considering their sensitivity) these instruments must be serviced periodically to insure accurate performance. The large plane operating companies, who use thousands of instruments, have found it necessary to install complete service plants for all their instrument equipment. The element of time involved in shipping to the manufacturer for minor calibration or repair was too great and too important. By having their own equipment, airlines can make repairs to meet flight schedules.

Born in Newark, N. J., John C. Banks received his early education in the Newark public schools and attended the Newark Technical School. In 1910 he completed a course in electrical engineering at Bucknell University and went to work for the Weston Electrical Instrument Corporation. The first World War interrupted this work, and Mr. Banks became an officer in the United States Navy. Since 1920 Mr. Banks has been connected with some of the larger electrical instrument companies. For the past year he has been employed by the New York School of Aircraft Instruments. His position is that of Instructor in charge of Electrical Instruments, and he is also in charge of all training given at the school to civilian employees of the Army Signal Corps. In recognition of Mr. Banks' inherent ability and knowledge, the instrument manufacturers have asked the authorities to allow all future training in electrical instrument repair of our armed forces and civilians in government employ to be under his supervision.—J.R.W.

When I look back over several decades of electrical instrument experience and then think in terms of today, the repair situation seems to have changed considerably. It is true that the public utilities have been making their own repairs for a number of years, but the transportation companies never took the time or trouble and sent everything to the manufacturer.

In the present war, the military use of electrical indicating instruments, even other than aircraft instruments, is enormous. The writer is spending all of his time training Army civilian employees the art of instrument repair and calibration. This work is done in two parts: the first part covering the mechanical repair of the instrument, and the second covering the electrical calibration and adjustment. In a production factory these operations are usually done by two different types of employees, some expert on one phase and the other group master of another type of work.

In training men and women for military repair work, it must be borne in mind that very often only one person at any instrument repair shop will have this specific knowledge. Therefore, in teaching Army employees it is vital to include all possible phases of this work. Since the military units are now using many types of electrical indicating devices, we must for the time being forget our allegiance to aviation and train them on all possible similar types of instruments to be found in many other fields. Electrical

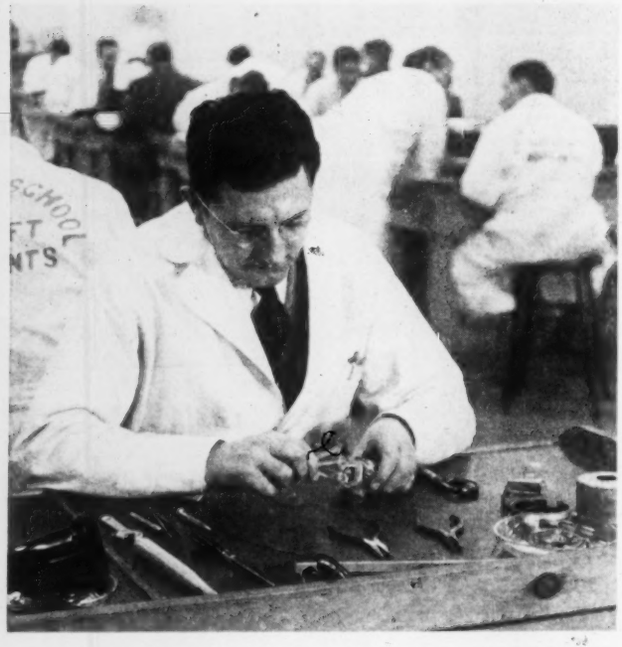
(Continued on page 490)

Aircraft Instrument Mechanics and the War

By E. D. WHITMAN
Director, New York School of Aircraft Instruments

TWO or three months ago a prominent antique silver dealer came into the school to discuss the opportunities for the mechanic in the field of aircraft instrument maintenance. The importing of antique English silver plate had come to a close. Where and how could this expert, at fifty, now make a living, and how particularly could he make a contribution to our war effort? As he had reasoned it out for himself, aviation would offer today and in the years to come the greatest opportunities. Our vast airplane building program, our training of large numbers of pilots, the conversion of our great automobile production plants to airplane building, must all result, according to him, in a spread of aviation during the war and after comparable to that of the automobile in the twenties. But could he, at fifty, school himself and then hope to compete in the fields of airplane or engine mechanics with the thousands of younger men who had graduated from the many schools in the country? A study of the possibilities in the aviation field led him to a decision: the least crowded of all fields, namely, aircraft instrument mechanics.

In his earlier years, he had been a silver worker and still considered himself capable of handling fine tools.



Student at New York School of Aircraft Instruments repairing magnetic tachometer.

Actually, all the school authorities required was that his eyesight be keen and his hands steady. And so today this man is enrolled and already on his way to becoming an instrument mechanic.

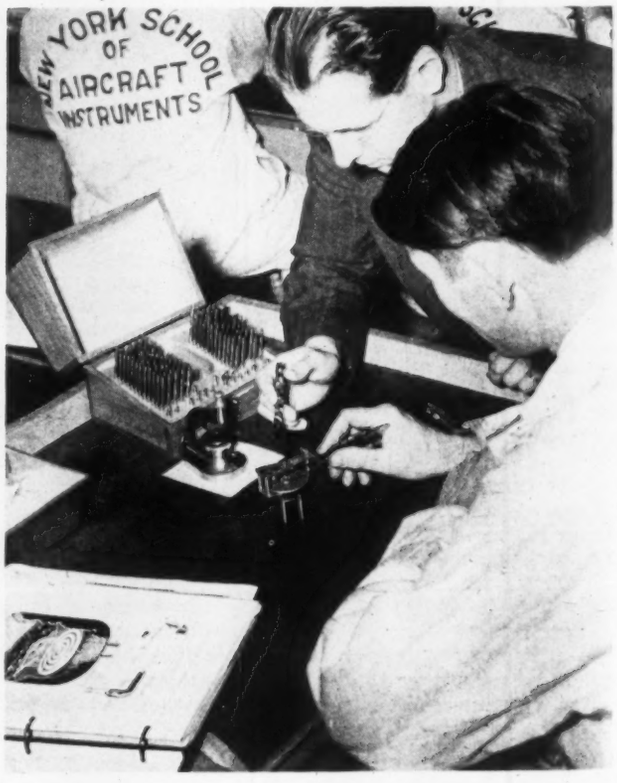
This case is typical of the hundreds who have come to us since Dec. 7th. No longer do we deal with the high-school graduate in search of a career, but with those who have become the casualties of priorities, of lost and forgotten markets, importing and exporting, etc. The middleman is no longer a middleman. We are reminded of a group who entered our school several months ago. Men of substance. They operated a chain of retail outlets, in New York City and several other large Eastern cities, of European and Levantine rugs, linens, etc. A far cry from mechanics, you would say. And still these chaps are doing a notable job. They are all becoming good instrument mechanics and not one of them ever had been other than a merchant during his working career. The patriotic motive inspires them all. This country has done much for them and they hope to contribute their bit.

And this contribution is a mighty necessary one in these days. Our construction of planes far outstrips our training of the much-needed maintenance crews, in every one of which the instrument man plays an important part. We have been enabled in the past year, from men such as these, to send in many soldiers and civilians to Army instrument depots, aircraft fields, and Naval Air Stations. Reports coming to us from these sources tell us of the efficiency of these mechanics. Many have become instructors of aircraft instrument mechanics, of navigation, of Link trainer operation, and the like.

The need for instrument knowledge appears in other allied fields. For the past several months our school has been training civilian employees of the U. S. Signal Corps. These men and women, coming from all the nine Corps Areas, are busily engaged in learning the repair, maintenance, testing, calibration, etc. of the instruments used on transmitters and receiving sets. The school, with great and helpful coöperation from the General Electric Co. and the Weston Electrical Instrument Co., has been enabled to offer a vital service in this emergency. Graduates from this course (men only) are invited to carry this knowledge so gained to our far-flung battlefields. It would be of interest to mention that many capable women are now enrolling as civilian workers in our Signal Corps, their work at our school ranking on a par with our male students.

The lack of instrument workers is now keenly felt by our airlines. The Army's and the Navy's needs have depleted the forces of the transportation companies so that all capable aircraft mechanics are assured of employment

(Continued on page 490)



Instructor at New York School of Aircraft Instruments explains instrument mechanism to student working on air speed indicator.

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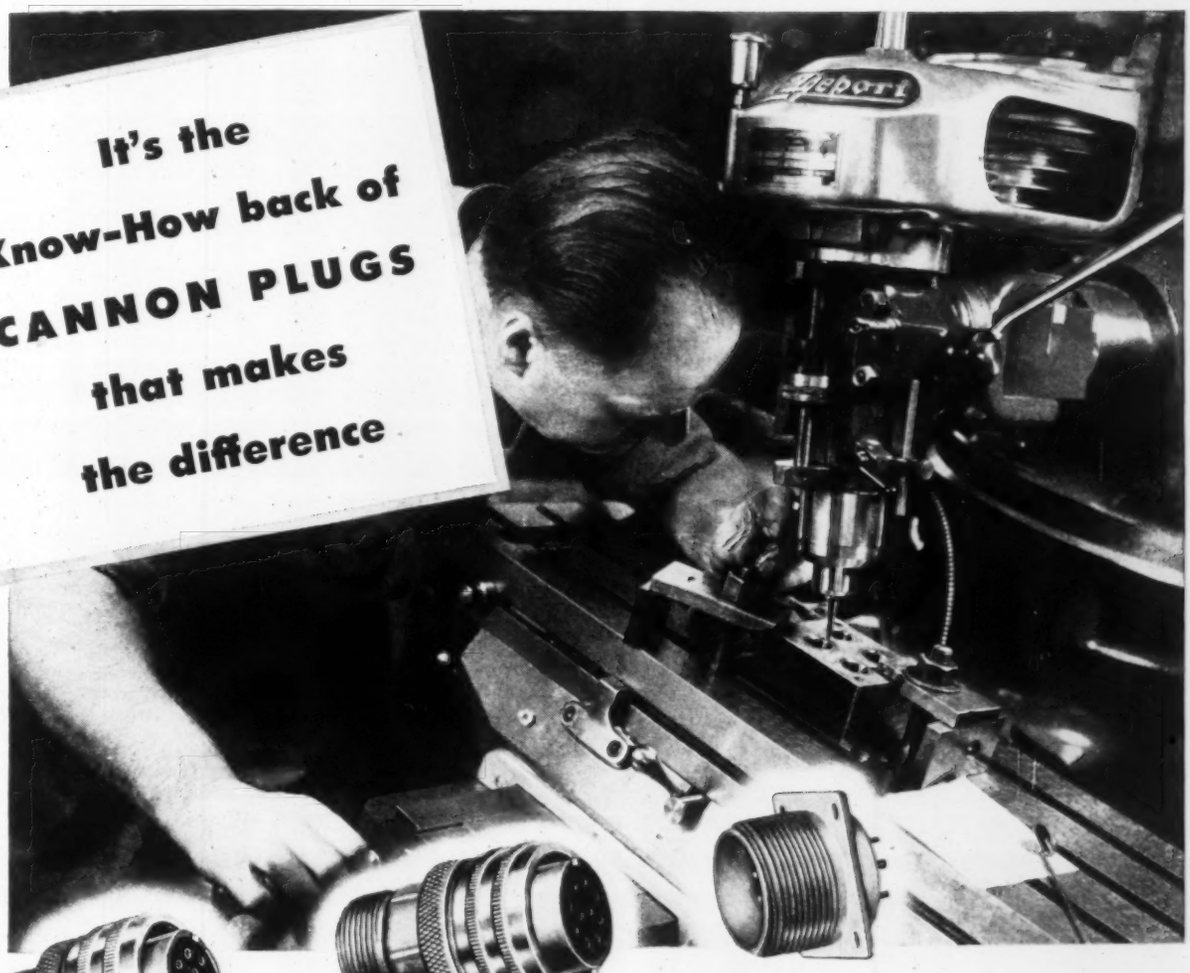

The makers of fine aircraft instruments are using Cannon Connectors extensively because they are built to give dependable service in carrying the important circuits from transmitting to indicating devices of many kinds.

Cannon is able to meet the varied needs of the instrument manufacturer because of long specialized experience in the connector field. The variety of shapes, sizes and contact arrangements in the complete Cannon line runs into the thousands. These fittings are all precision built. They are all backed with the *know-how* that assures satisfactory operation wherever electrical connections must be made quickly and securely.

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Electrical Aircraft Instruments

By R. W. GILBERT

Aircraft Engineering Division, Weston Electrical Instrument Corporation.

EARLY aircraft of World War I vintage had little or no electrical equipment. Night flying was infrequent and radio had not as yet advanced to the stage of practical service in aircraft. Also the weight penalty would have been serious in the early airplane types. Later however the institution of scheduled commercial night flying, particularly the early airmail services, required navigational and cockpit lighting, and communication equipment necessitating an electrical power system. The first installations were dry-cell-operated, but later the more practical lead storage battery and engine-driven charging generator of the automobile were adopted. This combination, refined to increase the capacity-weight ratio, is still the most extensively used system, although on extremely large craft the tendency is toward electrical power plants entirely separated from the main engines.

The necessity for control of the power plant introduced the first general requirement for electrical indicating instruments, usually a voltmeter and ammeter, or a combination instrument. Instruments for measuring other than electrical conditions, however, were still mechanical: vapor-pressure thermometers, Bourdon tube pressure gages, shaft-driven centrifugal tachometers, etc. But soon the increased application of multi-engine airplanes created a serious objection to the plumbing and other mechanical connections required by these instrument types, because of the increased length of the engine-to-cockpit runs. Also the military services objected to the vulnerability of such installations and to the complications created when changing damaged components such as engines and wings under battle conditions.

This situation forced adaptation of electrical methods for remote indication of engine operating factors, replacing pressure lines and other mechanical systems with electrical wiring, with its attendant advantages of flexibility and simplicity of installation and maintenance. Today electrical methods for indicating all engine conditions are in practical service and are being constantly improved to meet the increasingly exact demands of modern engines; for example fuel and oil pressure, oil carburetor and cylinder head temperatures, content of fuel and oil tanks, fuel flow, fuel-air ratio, manifold pressure, engine r.p.m., and position of radiator or cowl flaps. Also electrical indication of other than engine conditions requiring remote reading is extensively used, such as wheel and flap gear positions, outside air temperature and numerous other specialized measurements peculiar to military airplanes.

Thus in present-day practice virtually all remote measurements are made electrically and, as a class, electrical devices for measuring other than electrical conditions in number far exceed the conventional electrical instrument group of voltmeters, ammeters, etc. The specific methods employed are usually old in the electrical art for example resistance and thermocouple thermometers, but have been of necessity further developed to perform satisfactorily under the severe conditions of aircraft service.

Thermocouple Thermometers.—For the higher order of engine temperatures, such as air-cooled cylinder head temperatures, the thermocouple-and-millivoltmeter type of thermometer is almost exclusively used. The indicating instrument is usually cold-end compensated by means of a temperature-sensitive bimetal spring operating one of the movement control torque springs and consequently requires compensating leads which must be adjusted to a specified resistance. Iron-constantan and copper-constantan systems are both in general use, with leads adjusted to 2 ohms or 8 ohms resistance for small and large airplanes respectively. On extremely large airplanes, where calibrated leads of sufficiently low resistance would be cumbersome, the services of a flight engineer are usually available and the potentiometer type of pyrometer is sometimes used.

The thermocouple* is generally located under the top cylinder spark plug and is designed to replace the spark plug gasket. Otherwise it is a rivet or stud mounting type mounted on the head or base of the engine cylinder.

Resistance Thermometers.—Aircraft service conditions will not permit reliable millivoltmeter thermometer designs having ranges much below 500°F., so the lower order of engine temperatures, such as carbureter, oil and coolant temperatures, are usually measured by means of resistance thermometers.

The temperature-sensitive element or "resistance bulb" is specially designed to withstand the heavy vibration encountered in engine mounting and is hermetically sealed to prevent entrance of engine oils which contain corrosive organic acids. Also when used for carburetor temperature measurements it must withstand the transient high temperatures of engine backfires. The original aircraft resistance bulbs were wound with copper wire adjusted to 100 ohms at 25°C. Copper later proved an unsatisfactory material and a nickel-constantan combination was substituted, adjusted to approximate the original adjustment as closely as possible. The current Army-Navy standard temperature-resistance curve is based upon this adjustment, assuring interchangeability of bulbs and instruments without loss of calibration.

The indicating instrument contains a fixed bridge circuit, one arm of which is the temperature-sensitive bulb. The bridge unbalance in response to temperature change operates the electrical indicating mechanism which may be a deflection galvanometer calibrated in terms of temperature. Where independence of variations in the supply voltage is necessary the indicating mechanism is a ratio type similar functionally to those used in portable high-voltage insulation resistance measuring sets. With the galvanometer type of mechanism, the maximum independence of supply voltage variation of which this type is capable is obtained by balancing the bridge at the scale temperature at which maximum accuracy is desired.

Electrical Engine Tachometers.—The first remote electrical engine tachometer system consisted of a permanent magnet d-c. generator connected to a voltmeter type indicator calibrated in engine r.p.m. As the generator voltage must be accurately proportional to the engine speed some difficulty was experienced with commutation when the generator flooded with engine oil or was subjected to excessive vibration. In the interest of dependability a-c. tachometer generators having a rotating permanent magnet and stationary coils were developed, and the indicating instrument converted to a-c. operation by the addition of an instrument rectifier. This type of generator has no commutator or slip rings and, excluding actual mechanical damage, will function under severe conditions.

Another method in extensive use consists of a tachometer indicating head of the type previously shaft-driven, but substituting an a-c. generator and synchronous motor for the mechanical shaft. The usual combination is a magnetic drag tachometer head driven by a three-phase generator-motor system designed to stay in synchronism over a wide speed range.

Synchroscopes.—In multi-engine aircraft it is desirable to synchronize engines to reduce beat frequency vibration and maintain balanced engine power outputs. To this end synchroscopes designed to connect between the electrical tachometer generators are extensively used. This is usually a miniature differential motor driving a rotary scale or pointer, the direction and speed of rotation indicating the relative speed and direction of any two engines. The syn

*See: "Aircraft Thermocouples," by R. D. Kelly, Sup't of Development, United Air Lines. *Instruments*, Vol. 14, Oct. 1941, pages 298-300, 308.

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The instrument is used to measure cylinder head temperature, engine base temperature, oil temperature, carburetor air temperature, and free air temperature. It also has many other applications, which we cannot emphasize until the war is won.

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chroscope may be connected directly to the tachometer generators in a three-phase system, or through a phase-splitting circuit to single-phase generators.

Position Indicators.—Remote indication of the position of moveable members of the airplane structure, such as wheel retracting gear and landing flaps, in some cases is accomplished by simple switch and indicating light circuits. However, the serious consequences of malfunctioning of these members often warrants the use of a more complex indicating system capable of continuous indication of their position. The standard a-c. Selsyn type of self-synchronous positioning motor familiar to marine and industrial service has been adapted to aircraft by reductions in size and weight. However, this system requires an alternating current power source not normally available in aircraft, necessitating a d-c. to a-c. converter, limiting its application in favor of d-c. systems.

For direct operation from the airplane d-c. service power the so-called d-c. Selsyn system has come into extensive use. This basically is a potentiometer rheostat operated by the moving member and connected to an indicator calibrated in terms of position, or carrying a graphic representation of the movable member. To secure freedom from supply voltage variations, the indicator is usually a simplified type of ratio mechanism. The most commonly used structure consists of an iron ring carrying three coils connected to the rheostat within the ring. As the currents in the coils vary in response to rheostat operation, the magnetic flux across the ring diameter changes direction, rotating the moving element to provide the indication.

Mechanisms that are essentially position indicators are also used to transmit indications of pressure, temperature, etc., by the use of appropriate translating elements connected to the position transmitter unit. For example, fuel tank level gages operate by remote indication of the position of a float in the tank.

Fuel Flow Meter.—Indication of the rate of fuel consumption by the engine is important for setting engines to maximum cruising efficiency. They usually consist of a mechanical flow mechanism operating an electrical transmission system. One type of transmitter contains a small vaned permanent-magnet rotor driven by the gasoline flow, rotating within a fixed wound field structure so that it is essentially an a-c. generator the output of which is proportional to rate of flow. An a-c. voltmeter calibrated in terms of fuel flow is used as the indicating instrument.

Fuel/Air Ratio Indicators.—The aircraft mixture proportion indicator is the hot-wire bridge exhaust gas analyzer type widely used in the automotive industry. This is essentially a resistance thermometer arranged to respond to the thermal conductivity of the exhaust gases, although unfortunately the output of the bridge is insufficient to operate a ratio type indicator. The galvanometer type indicator is used and the bridge current is stabilized against supply voltage variations by a hot wire ballast lamp.

Miscellaneous Instrument Applications.—Specialized measuring or remote indicating electrical equipment designed for specific airplane types is widely used, particularly in military craft. Also, in equipment such as the radio altimeter and radio compass, indicating instruments are a small but necessary portion of the system. Radio communication equipment also makes extensive use of more or less conventional electrical instruments, either permanently installed or arranged for plug-in connection for servicing. The probable future extensive use of a-c. power plants operated independently of the main engines will require aircraft editions of a-c. power instruments: ammeters, voltmeters, wattmeters, power factor meters, etc. Polyphase power units having ratings as high as 50 kva. are not beyond reason, and will warrant complete instrumentation for efficient operation and servicing in flight.

Installing and Operating the Gas Analyzer

By BENJAMIN KREDERAVAGE
Instructor, New York School of Aircraft Instruments

IN previous years, a great deal of flying was done without any means of determining the exact fuel-air mixture ratio. To conserve fuel and to obtain the maximum efficiency from aircraft engines, the exhaust gas analyzer system was designed.

By the analysis of the exhaust gas this instrument shows the mixture in fuel-air ratio. This is brought about by drawing a sample of the gas from the exhaust stack and passing it through an analysis cell where it is electrically analyzed, the analysis being indicated on the instrument.

Principle of Operation.—The instrument's operation is based on the thermal conductivity principle, four platinum spirals forming the four legs of the Wheatstone bridge circuit, two being exposed to moisture-saturated air and two being exposed to the gas under test. The spirals are heated a definite amount by the current, and remain in balance as long as the surrounding gas is of similar conductivity. When the two test spirals are exposed to the exhaust gas, the resistance varies—depending upon an increase or decrease of the heat conductivity of the gas under test. This is in comparison to the two standard spirals which are exposed to moisture-saturated air. The variation of resistance will cause the bridge to unbalance resulting in a deflection of the pointer.

CO_2, H_2, O_2, CO, CH_4, and H_2O are the component gases making up the complete exhaust. The fuel-air ratio value depends on the proportion in which these gases exist.

Installation.—The equipment consists of one analysis cell for each engine, and one indicator. A junction box, or a means of controlling the current, is used in conjunction with this system. The necessary accessories for conducting a sample of the exhaust gas from the engine through the cell include sampling elbows, copper tubing, and rubber connectors.

The analysis cells are mounted so that the sampling lines point upward to insure proper drainage of condensation. Two gas sampling elbows are used with each analysis cell, one mounted in the exhaust stack facing the flow of gas, the other placed directly behind the intake elbow and turned with the flow of gas. The intake elbow must be located at a point where we receive a positive flow of gas to insure a proper flow to the cell, and it is generally found by trial and error. A short length of steel tubing is used to join the sampling elbows to the sampling lines running to the analysis cell. This prevents damage to the copper lines and fittings due to heat. The sampling lines are joined to the analysis cells by means of rubber tubing to prevent transmitting of vibration from the sampling lines to the cell unit.

The junction box is generally installed in the pilot's compartment and is shock mounted. The box must be within reach of the pilot for current calibration. The indicator is mounted on the panel where it is clearly visible to the pilot. The junction box maintains a steady supply of voltage to the various parts of the system. By means of a rheostat in the junction box, the current which operates the system is regulated to the output required to heat the spirals of the cell block to a given point.

After the exhaust analyzer system has been completely installed, the following points of instrument adjustment are made.

(1) Mechanical zero is adjusted. With the current switch in "off" position, the pointers of the instrument should rest exactly on "A." There is a small adjusting screw which

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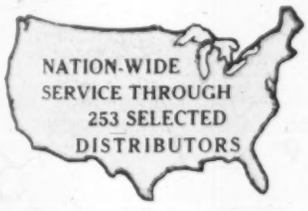

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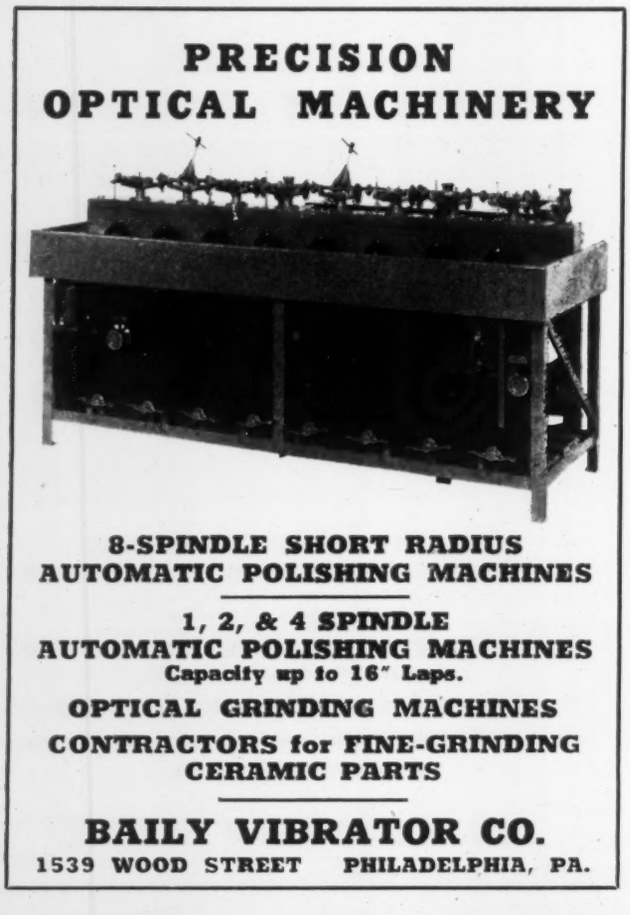

may be adjusted to compensate for any mechanical error at zero position.

(2) The current adjustment is used to obtain a constant value of current. To check this, the current switch is turned to the "Standard" position. If the pointer is out of adjustment, it can be brought into adjustment by turning the rheostat knob. Later models eliminate the use of the junction box, and the standard adjustment is set within the instrument in the overhaul shop.

(3) Electrical zero should then be checked, and the pointer should rest on "A." If any error is present the following procedure is used to correct it. The cover and steel wool are removed from the analysis cell, and a water-dampened rag is placed inside the filter compartment. No residual gas from previous use of the system should be present, only pure air. The instrument remains so for about 20 minutes and then the switch is turned to "on," whereupon the pointer should return to "A" in a short period of time. If it does not, adjustment is necessary and is made by turning the rheostat in the cell unit. After the test is finished, the steel wool and cover are replaced.

The instrument can be read to a fair degree of accuracy for mixtures leaned to 0.068 fuel-air ratio.

For checking the exhaust gas analyzer system a field test stand is used. This consists of two tanks of gas; one containing lean gas and the other containing rich gas. The tanks can only be purchased from the manufacturer. Each tank is equipped with a pressure regulator and gages. Metal tubing is used to connect the cell to the low-pressure side of the regulator which is connected to the tank. Rubber couplings are used to attach the tubing itself to these units. The outlet of the gas is connected to a small jar of water, by means of which the flow of gas can be observed and regulated.

With the pressure regulator opened, the tank valve is opened until the pressure is registered on the dial gage. This pressure is regulated until a proper flow of gas is obtained. The lean test gas is run first until a steady deflection of the pointer is present. After the deflection stops a reading is taken, and it should correspond, within ± 0.0015 F/A, to the reading on the tank. After this reading is checked, the cell is connected to the rich tank and the same procedure is followed; except that a tolerance of ± 0.0025 F/A is allowed when checking the rich gas. If these tests prove satisfactory the system is ready for service.

Gyros: Unknown Heroes

By PAT ROMANELLI

Instructor, N. Y. School of Aircraft Instruments

THIS war has developed many heroes in the form of flyers, but little or nothing is ever mentioned of our flyer who deserves some honor. He is the Automatic Pilot or Gyropilot. Few people realize the importance of this mechanical brain.

As you know, a pilot flies by "the seat of his pants" and by eye; therefore he is limited. When adverse weather conditions and night flying are encountered, a plane not equipped with a Gyropilot or other blind flying instruments is grounded. Now, as you have read, some of the most devastating raids of the war have been carried out at night; and long-distance bombings have been executed in the Pacific theatre. These could not have been accomplished were it not for our mechanical servant.

The Gyropilot was developed by the Sperry Gyroscope Co., makers of other precision blind-flying instruments. It consists mainly of two parts: the instrument, or the air control unit, and the mechanical, or hydraulic unit.* All parts within the instrument are held to incredible tolerances of

*For a description, see:
"Development and Principles of the Gyropilot" by PRESTON R. BASSETT, Vice-President and Chief Engineer, Sperry Gyroscope Co. *Instruments*, Vol. 9, Sept. 1936, pages 251-254.—ED. *Instruments*

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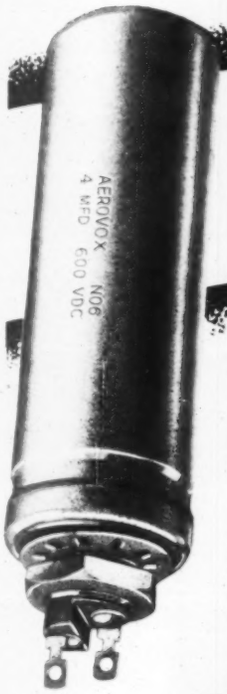

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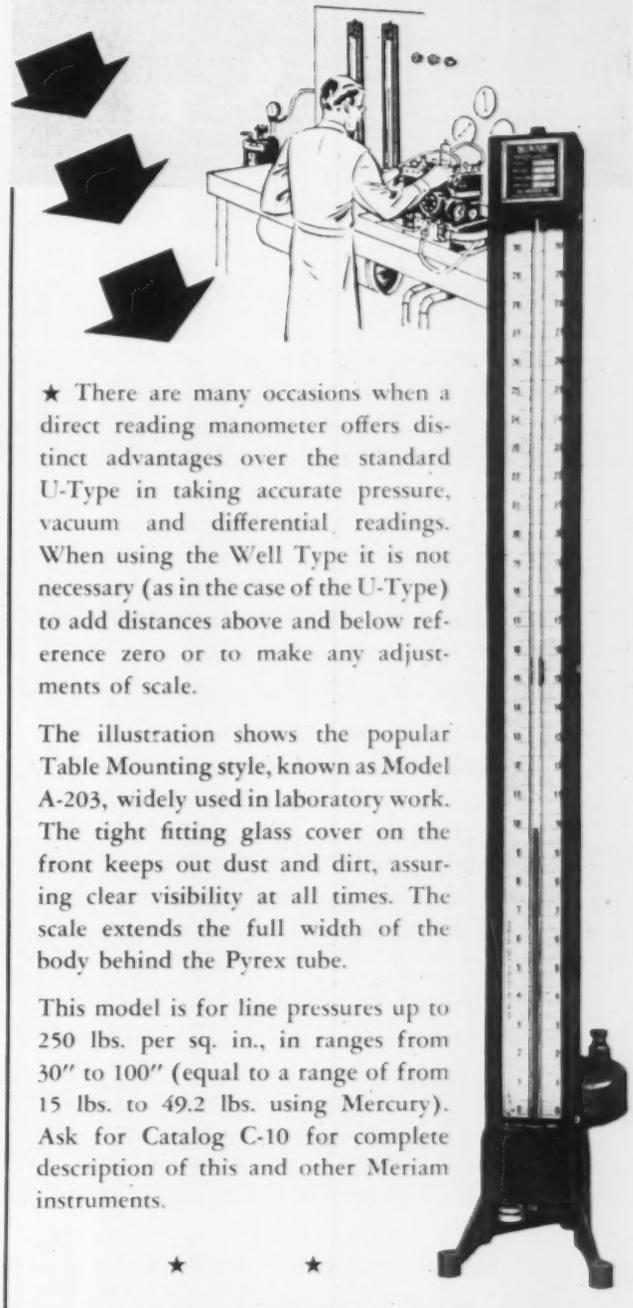

★ There are many occasions when a direct reading manometer offers distinct advantages over the standard U-Type in taking accurate pressure, vacuum and differential readings. When using the Well Type it is not necessary (as in the case of the U-Type) to add distances above and below reference zero or to make any adjustments of scale.

The illustration shows the popular Table Mounting style, known as Model A-203, widely used in laboratory work. The tight fitting glass cover on the front keeps out dust and dirt, assuring clear visibility at all times. The scale extends the full width of the body behind the Pyrex tube.

This model is for line pressures up to 250 lbs. per sq. in., in ranges from 30" to 100" (equal to a range of from 15 lbs. to 49.2 lbs. using Mercury). Ask for Catalog C-10 for complete description of this and other Meriam instruments.

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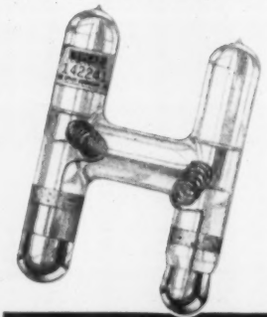
LESS than a generation ago high quality in industrial products implied scarcity. Today mass production is compatible, even synonymous, with quality.

One secret of this seeming paradox is accurate automatic control where high, uniform temperatures are required, — a control which is frequently remote from the scene of operation.

Such control is possible only with potentiometric instruments and the latter are possible in most cases only because of Eplab Standard Cells, which provide a yardstick for the translation of voltage to temperature.

If your processing involves high temperatures, use potentiometric instruments to assure uniformity of output, and for LASTING accuracy make sure the standard cells are EPLAB.



EPLAB STANDARD CELLS
FOR POTENTIOMETRIC INSTRUMENTS
"AS STANDARD AS STERLING"

THE EPPLEY LABORATORY, INC.
SCIENTIFIC INSTRUMENTS
NEWPORT, RHODE ISLAND, U.S.A.

Instructor explaining intricate mechanism of Sperry Gyroscopic instrument. Directional Gyro.

one thousandth or one ten-thousandth of an inch—some to a hundred thousandth of an inch. Every part in the final assembly is hand-fitted and the instrument is passed through a series of inspections before being shipped.

The movements of the plane covered are Bank, Climb and Direction. Any deviation from its set course or its true flying position are corrected immediately by the instrument. Its sensitivity exceeds by far that of our best pilots and it can be relied upon to get our men to their destinations and back unfailingly. It relieves the pilot from the controls so that he can concentrate on his radio or get a much-earned rest.

Its use is not only in war, but also in peace. Every cargo or passenger plane is equipped with the instrument, making night flying and poor-weather flying possible.

I can foresee that in the very near future we will be flying solely by radio controlled gyropilots, with the human pilot concentrating on his engines and navigational problems.

You can see now the importance of this unsung mechanical robot, which flies unerringly regardless of weather and other conditions, and which is actually the pilot behind the pilot in which our flyers put faith and trust.

Facts and Figures on Students

By J. R. WHITMAN
Registrar, N. Y. School of Aircraft Instruments

A RECENT SURVEY at the New York School of Aircraft Instruments indicates a rise in the age of the average student. Today's student is approximately thirty years of age, married, and has had at least two years of college training. This is in line with the trend at all private technical schools.

More women are preparing for defense work than ever before. All large construction companies in aviation now employ women in various capacities, and the experiences of these companies with women workers has been favorable.

Both men and women, today, are more serious in their purpose and training than ever before. No doubt the war effort and the fact that many industries are being hit by priorities create an incentive to get into production work to help beat the Axis.

Another finding of the enrollment survey indicates a great diversity in student background. The student body at the New York School of Aircraft Instruments is composed of men and women from all walks of life. Doctors, dentists,

(Continued on page 488)

Tough ... YET SENSITIVE TO .0025 OF AN INCH!

THE HAYS slack leather diaphragm of colon leather retains its natural oil indefinitely, remains soft, pliable and sensitive to slight changes in pressure over a long period. Its the toughest pliable substance known, successfully withstands sudden pressure shock. New book "Draft-What-Why-Where" tells all about draft and draft measurement. Send for your copy today.

The HAYS CORPORATION
SINCE 1907 — COMBUSTION INSTRUMENTS AND CONTROL
MICHIGAN CITY, INDIANA, U.S.A.

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PERMOPIVOTS*
TIPPED WITH PERMOMETAL* ALLOY

PERMOPIVOTS are tipped with a special alloy which has the following exceptional qualities:

- **WEAR RESISTANT...** The Permometal tip gives precision instruments longer life and greater accuracy under actual operating conditions.
- **NON-CORROSIVE...** Permopivots cannot rust or corrode.
- **NON-ABRASIVE...** The satin-smooth tip eliminates abrading particles of wear.
- **ELIMINATES OIL...** It is often possible to eliminate oil because of the extremely low coefficient of friction with Permopivots.

* T. M. REG. U. S. PAT. OFF.

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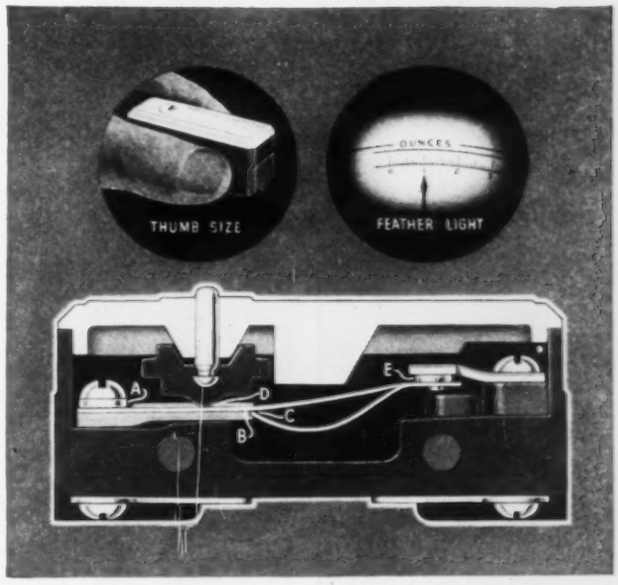
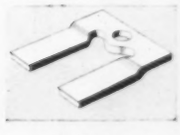


Why These Basic Principles of Micro Switch Design Assure You . . .

- **Longer switch life than you will ever need**
- **Absolutely precise and accurate repeat operation**
- **40 grams contact pressure—lightning-fast contact action**

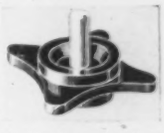
The Micro Switch design incorporates features that provide desirable performance characteristics not generally found in snap-action switches . . . The heat-treated beryllium-copper spring bends in the same direction as the operating plunger—no reverse bends—no "oilcan" action . . . gives longer switch life—accurate repeat action—increased contact pressure—lightning-fast action—millions of operations on minute movement and force differentials. It is the choice of design engineers for all types of sensitive instruments.

The beryllium-copper spring is made in one piece. It is gauged to an accurate .0085" thickness; has high resistance to fatigue. Ends of compression members are finished to provide an extremely low friction bearing. Contact end of the spring is fitted with a riveted radius type contact of 99.95% fine silver. It moves at a speed of 3 1000ths to 5 1000ths of a second with a rolling action and extremely high pressure.



Short spring members pivot in patented V-grooves of this sturdy brass anchor. Note the special shape of these grooves, which reduces friction to a minimum.

Stationary contact is a flat inlay of 99.95% fine silver. This construction assures ample over-load capacity and maximum heat dissipation.



Operating plunger is a highly polished stainless steel pin imbedded in an accurately moulded star-shaped Bakelite head. Provides long over-surface path to live parts, thus insuring freedom from electrical leakage. Plunger head cannot rotate within the housing, insuring against any variation in point of operation.

If you would like to know more about the Micro Switch, send for the two Handbook-Catalogs illustrated here—No. 60, which covers Micro Switches in general; and No. 70 which deals with specific Micro Switches for use in aircraft.

Micro Switch is a trade name indicating manufacture by Micro Switch Corporation

MICRO MS SWITCH

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Branches: 43 E. Ohio St., Chicago • 11 Park Place, New York City
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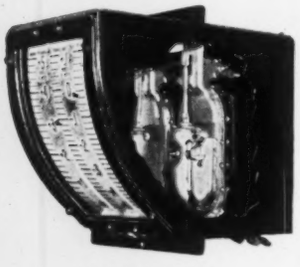
METERS and CONTROL
for Boiler Room Service . . .

Boiler Meters Reduce fuel costs, lessen maintenance and outage, lower standby costs, and add capacity. They indicate, record and integrate Steam Flow from the boiler, record Air Flow supplied for combustion and record Flue Gas Temperature.

Bailey Boiler Meter

Multi-Pointer Gages for indicating drafts, pressures, differentials are available with any number of pointers from one to twelve. They are actuated by sturdy yet sensitive diaphragm units.



Multi-Pointer Gage

Flow Meters. For indicating, recording and integrating the flow of steam, feed water, compressed air and other fluids.

Coal Meter

Granular Material Meters For accurately measuring the flow of coal or other granular materials in gravity chutes from overhead bunkers. The total quantity of granular material is shown on a large illuminated counter which may be easily read at a distance of 50 feet.

Control Systems Make possible the everyday operation of equipment for steam generation and utilization at test efficiencies. They are applied to the control of combustion, feed water, superheat, desuperheat and other factors.

Complete Information on any of the above Bailey products will be gladly furnished upon request.

G-14

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BAILEY METER COMPANY LTD., MONTREAL

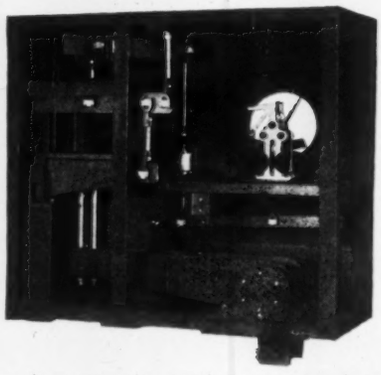
The Month's NEW INSTRUMENTS

In this department we strive to report each month ALL the new devices for measurement, inspection, testing, metering and automatic control—in the form of concise technical descriptions. When writing to manufacturers directly, please mention this department as your source of information. Or write to Information Section, Instruments Publishing Company.

Drawbar Dynamometer for Aircraft Control Cables

New Drawbar Dynamometer Scale is announced for testing control cables used in aircraft assembly. The test can be applied to the control cables themselves and to their swedged fittings. Makers are in production on drawbar dynamometers of

30,000-lbs. capacity and dial chart is made up to show this total capacity with 25-lb. graduations. Dial is equipped with both an indicating pointer and a dead needle, the latter remaining in position to indicate

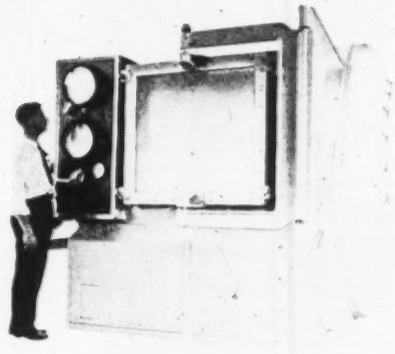


final tension at which the cable ruptured or the swedged fitting pulled off, should the test be for ultimate strength. Usual test is, of course, to prove "guaranteed" strength. Tension is created by a hydraulic piston and cylinder which uses city water pressure to take up initial slack and a hand-operated hydraulic pump to produce primary force for the ultimate tension test. Cables to be tested are connected end-on-end and roved back and forth between the two sets of sheaves for multiple testing. Adaptors to connect the cables end-on-end usually consist of two clevises connected by a turnbuckle for connecting between eyes of swedged tips. Other types of connectors which clamp on the cable itself behind the swedged tips can be designed for each different size of cable. By placing the hydraulic pump at the same end and in front of the dynamometer head, one man can operate the entire device.—*The Kron Co., Bridgeport, Conn.*

"Stratosphere Chamber"

[Corrected item—disregard the one in Oct. issue]

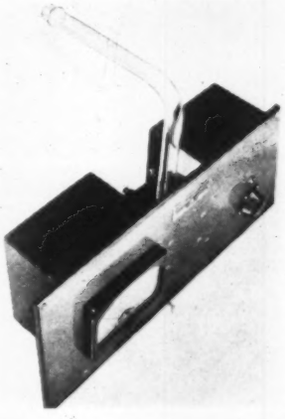
For testing mechanical parts of aircraft as well as radio used in high-altitude work, "Stratosphere Chamber" has an inner chamber volume of approx. 245 ft.^{3}; operates between temperatures of 200°F. and −75°F. with an internal pressure variation from ambient at location of unit to 3" of mercury absolute. Both the pressure and temperature



variations are controllable throughout their ranges. Freon-12 is used as the refrigerant. Refrigeration effect, or heat acceptance from the chamber, is by forced convection through coils designed for low-temperature work. Each coil will accept a minimum of 200 B.t.u. per degree at −75°F. and 3" mercury pressure. Humidity control is from 25% to 95% relative at all temperatures above +40°F., or at a fixed bottom temperature of 32°F. Below this level, absolute humidity will correspond to air saturation at coil temperature, which will average 15° to 20° lower than chamber temperature. Heating equipment for higher temperatures comprises strip heaters so arranged that forced convection circulates air during the heat cycle. Three indicating recorders are provided for continuous recording of temperature, pressure and humidity. Twelve mechanical connector shafts through outer shell of chamber project inside the liner, for attaching a flexible shaft, an angular rigid shaft or a small belt drive to any mechanical part that may be mounted in test position in the chamber. Eighteen electrical connections are provided. A separate machine compartment is located back of the unit, but may be placed adjacent to the end.—*Kold-Hold Mfg. Co., Lansing, Mich.*

Continuous-flow Colorimeter

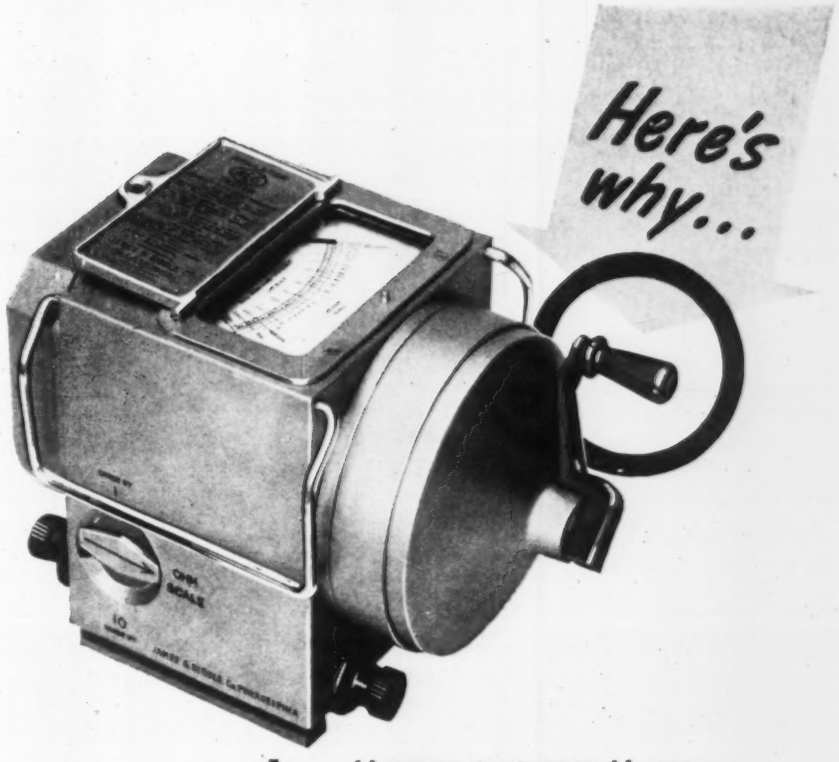
New "Lumetron Colorimeter Model 400-S" indicates spectral transmissivity of a liquid passing continuously through it. Operating principle is similar to that of usual photoelectric colorimeter: light of an incandescent lamp passes through a color filter and through the liquid, then impinges upon a barrier-layer photocell whose output actuates an electrical indicating instrument. Distinctive feature is that liquid under test passes through a glass tube instead of being contained in an absorption cell or a test tube. This makes the instrument suitable for continuous control of chemical processes in which the color or turbidity of a liquid must be checked either as a measure of its concentration or as an indication of some other chemical or physical condition. Once calibrated by means of a



solution of known concentration, instrument indicates the concentration directly and continuously, obviating the necessity of taking samples and analyzing them at regular intervals. Instrument is designed to be mounted on a panel or control board. The instrument panel carries, on its front side, the electrical indicating instrument, an on-and-off switch for the lamp, and a control knob for standardizing. The light of a 50-watt incandescent lamp is collimated by a condensing lens system. It passes through the glass tube and through a color filter before striking the photocell. Dial carries a scale indicating transmission in percent and a density scale which, in most instances, gives readings directly proportional to concentration. Choice of filter depends upon color or solution under test. Instrument has ample sensitivity for use of highly selective color filters isolating narrow spectral bands. Filters can be interchanged. A constant voltage transformer provides constant light output of lamp even if line voltage fluctuates.—*Photovolt Corp., 95 Madison Ave., New York City.*

Thermoscopic Paint

Employing the same principle as the "Tempil° Pellets" and "Tempilstiks°" previously described in this department, new "Tempilaq°" liquid is available in a wide range of pretermined melting points between 125° and 1600°F. A thin smear or daub is applied to the working surface and dries "in an instant." When temperature stated on the Tempilaq° bottle is reached, the smear liquefies sharply. On cooling, it solidifies, leaving a glossy or vitreous mark distinctively different from the original smear. Being a liquid, Tempilaq° can be used on glass, wood, ceramics or plastics as well as on metal and is the more convenient form for use on polished surfaces, on inside of tubes or castings and in other inaccessible places such as overhead surfaces. The 1½ oz. bottle will give over 300 determinations. Free samples.—*Tempil Corp., 132 West 22nd St., New York City.*



...the "MEGGER" Tester is *ALWAYS READY* for use

When the need arises for emergency insulation testing of electrical equipment—it calls for immediate and positive action. "Megger" Insulation Testers are *always* ready for use, day or night, even in the most remote, isolated, inaccessible locations. The self-contained hand-cranked generator is a source of power that is reliable and wholly independent of any battery or other outside source. The "Megger" Tester is a complete unit in itself.

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Flare type FITTINGS make it possible to install a complete system with no more tools than a sharp knife and a screw type flaring tool.

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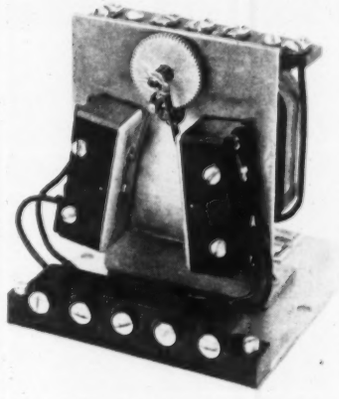
"Motorelay"

New "Motorelay" is used with any floating contact device in applications where the control current exceeds the contact rating of the control instrument. Features: The construction of the Motorelay includes a



shaded-pole reversible geared head motor, totally enclosed switches, and switching mechanism. An enclosed type drawn steel cover is available. Switch contacts have a non-inductive load capacity of 10 amperes at 110 or 230 volts a.c. Control circuit current is 0.35 amperes at 25 volts.—*Barber-Colman Co., Rockford, Ill.*

Cathode-ray Oscilloscope

Wartime requirements are said to be responsible for new "Type 224" cathode-ray oscilloscope characterized by greatly extended frequency range, more versatility

in handling of applied signals, and special pickup means whereby input capacitance is reduced and stray pickup eliminated. Removable front cover protects panel, controls and tube screen, and holds shielded-cable test probe, when instrument is not in use. An outstanding feature is the Y-axis or vertical deflection response which is uniform from 20 c.p.s. to 2 Mc. It has a comparably faithful square and sinusoidal wave response. The X-axis or horizontal deflection amplifier has a uniform characteristic from 10 c.p.s. to 100 kc. Both amplifiers have distortionless input attenuators and gain controls. Wide variety of signal input connections available. In addition to conventional amplifier connections, signals can be applied directly to deflection plates of 3" cathode-ray tube, when desirable, by means of terminals at front panel. The Y-amplifier has an input connection for "Shielded-Cable Test Probe Type 242A," supplied with instrument, which reduces input capacitance

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4 Diff. Ranges in ONE Unit

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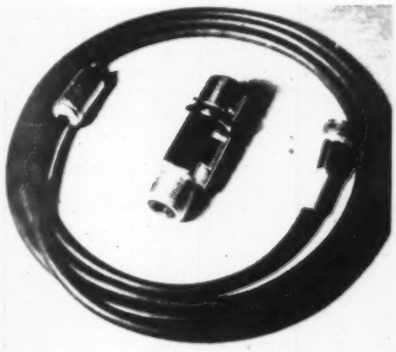
and ...inates stray pickup. All high-volt... ...trolytic condensers are eliminated ...from ...cuit. New instrument weighs 49 lbs., and ...sures 14⅛" high, 8⅝" wide, 15⅛" deep. ...operates on 115 volts, 60 cycles a.c. —... *B. Du Mont Laboratories, Inc., 2 Main ...ve., Passaic, N. J.*

Engine Knock Measuring Apparatus

The determination and study of knock or detonation in gasoline and Diesel engines is made possible by the use of a new detonation amplifier and a new engine pressure pickup. These two instruments are employed with an oscillograph for visual study of the detonation wave shape, or may be employed with an earphone for audible indications:—

(1) Pressure Pickup for Gasoline or Diesel Engines

New "Type PU224" pickup is of the magnetic type and consists of a diaphragm, a permanent magnet, and a coil especially insulated to withstand the highest tempera-



tures encountered. Pressures acting upon the diaphragm change an air gap, which in turn causes a change of magnetic flux through the coil, which change generates a voltage therein. Suitable for general engine pressure work this new pickup is said to have "a number of features not found in any other pickup." For detonation work the signal from the pickup is fed into the new Detonation Amplifier described elsewhere in this issue. The pickup has approximately the same size and shape as a ⅞"-18 spark plug and has the same thread. It is supplied with a detachable six-foot shielded cable.

(2) Detonation Amplifier for the Determination and Study of Detonation in Gasoline and Diesel Engines

New "Type DF60 Detonation Amplifier" is selective and tunable to any frequency between 2000 and 12,000 cycles per second.

Hence, it amplifies only the detonation signal to which it is tuned and reduces all other signals to negligible values. It actually amplifies the detonation signal as much as 300 to 600 times, depending upon the frequency. It is completely enclosed in a black crackle steel case approx. 7" high × 10" wide × 7" deep.—*Rowe Radio Research Lab. Co., 4201 Irving Park Blvd., Chicago, Ill.*

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Production or Research Instruments

Weksler Thermometers are scientific, precision instruments. Their rugged construction and lasting accuracy will merit your full confidence. Red Reading Mercury tubes are standard in all V shaped bronze case industrial thermometers. Indicating and recording thermometers are furnished mercury, vapor or gas actuated. Dial indicating thermometers available in 3½, 4, 5, and 6 inch sizes. Recording thermometers furnished with 6, 10 or 12 inch chart sizes. There is a Weksler precision thermometer for every industrial need.

"V" Shaped Bronze Case Industrial

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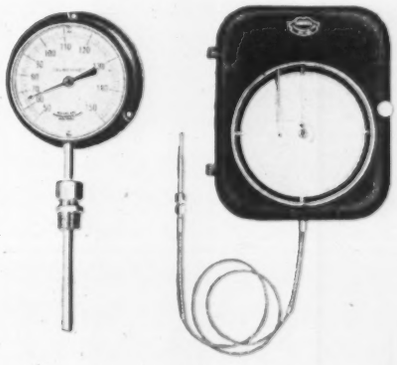
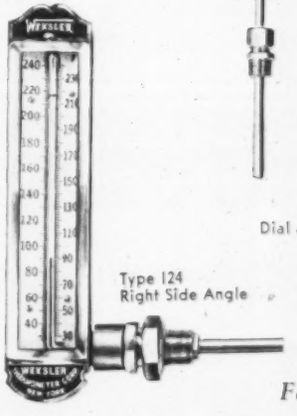
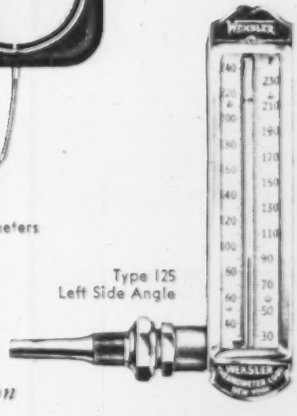


Dial and Recording Thermometers



Type 124 Right Side Angle



Type 125 Left Side Angle

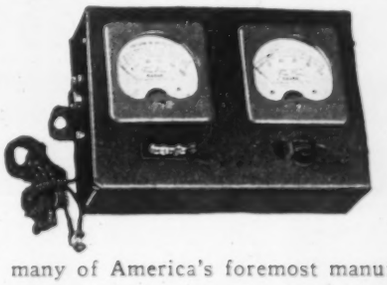
For information on

Dial and Recording Thermometers, send for Catalog 300 DR

For others, send for Catalog No. 115.

Weksler Thermometer Corporation

52-56 WEST HOUSTON STREET, NEW YORK, N. Y.



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WHEATSTONE BRIDGE

A high grade instrument for measuring resistances from a fraction of an ohm to 10 megohms. Contains a 4-dial rheostat, ratio dial, galvanometer and battery, all enclosed in a substantial walnut case. Nine coils per dial. Accuracy .1%. Built to endure.

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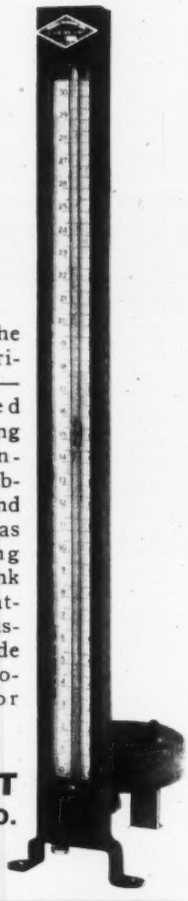

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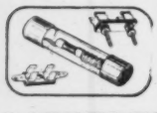

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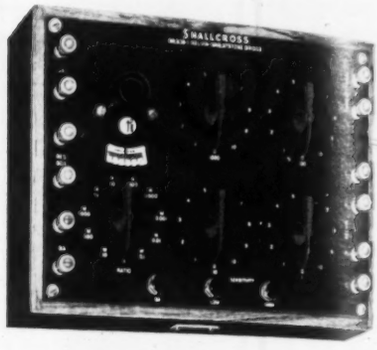
Experienced in repair and calibration of all types of electrical instruments. Steady position with established instrument house covering Pacific Coast industries. In defense work for the duration. Address application to L. R. Kettenring, President, c/o The Instrument Laboratory, Inc., 926-34 Elliott Avenue West, Seattle, Washington.

WANTED

Man, thoroughly grounded in physics or engineering with statistical leanings, to compile interpretive data resulting from experiments in research department of instrument manufacturer. Write Box No. 64, Instruments Publishing Co., 1117 Wolfendale Street, Pittsburgh, Pa.

Combination Kelvin and Wheatstone Bridge

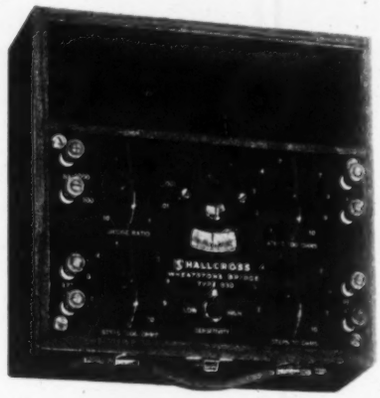
New "No. 638-1 Kelvin Wheatstone Bridge" combines in one instrument the circuits and requisite circuit-elements constructions of a Kelvin bridge and of a Wheatstone bridge with a built-in galvanom-



eter, in an oak case 12" × 9" × 4". Instrument has an effective range from 0.0001 ohm to 11,110,000 ohms. By using a source of current of considerable capacity (such as a single cell of a storage battery), resistance as low as 0.00001 ohm may be detected and measured. Wheatstone Range: Four rheostat decades 1, 10, 100 and 1,000 ohms. Limit of error 0.1% except 1-ohm coils 0.25%. Ratio dial multipliers: 1,000, 10, 1, 0.1, 0.01 and 0.001. All ratio coils matched within 0.1%. Kelvin Range: Four rheostat decades: 1, 10, 100 and 1,000 micro-ohms. Ratio dial multipliers: K1,000, K100, K10 and K1. Galvanometer sensitivity 1 microampere per millimeter division. Accuracy: With built-in galvanometer 0.3% on Wheatstone measurements and 5% on Kelvin measurements. If external galvanometer of high sensitivity is used, these may be reduced to 0.2% and 3.0% respectively.—*Shallcross Mfg. Co., Collingdale, Pa.*

Wheatstone Bridge

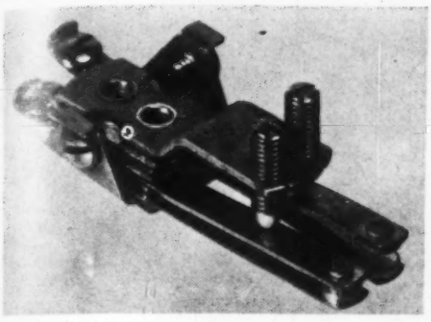
New "No. 630 Wheatstone Bridge" is characterized as a "basic electrical-measuring instrument for every laboratory and manufacturer." Its range extends from 0.1 to 11,100,000 ohms. Accuracy is 1% between 10 ohms and one megohm. The galvanometer has a sensitivity of 1 microampere per



millimeter division. Among the features are the following: The three decades of the rheostat arm are connected to external binding posts, thus enabling the bridge to be used as a resistance box from 10 ohms to 11,000 ohms in an external circuit. Each decade consists of 10 wire-wound resistors. These resistance units are wound with Manganin wire on a non-hygroscopic form. Switches have ceramic switch plates, brass contacts and multi-leaf phosphor bronze arms.—*Shallcross Mfg. Co., Collingdale, Pa.*

Duplex Thermostat

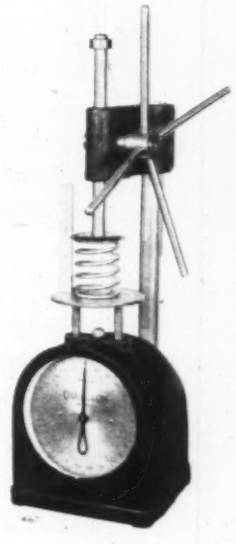
...w unit to be known as Duplex Thermo... ...is added to maker's line of SK Series ...ostats and is to be designated as ... Series." It is actually two thermo... ...in one. Stack pile construction makes ...nit compact and sturdy. Measuring ... × 1⅛" × ¾" it is easily mounted



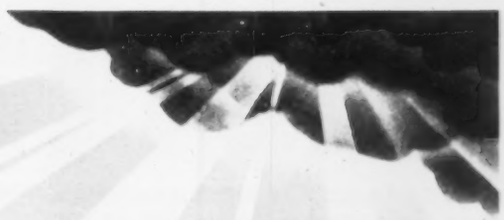
with two 6/32" screws through the eyelets which have ⅞" centers. Temperature ranges are 300, 450 and 700 degrees F. It can be connected as two single-pole single-throw switches, or as one s.p.d.t. switch. Recommended electrical rating is 500 watts non-inductive load at 115-230 volts a.c. Each individual thermostatic element is independently adjusted by its respective adjusting screw provided on the mounting bracket. There are three contact combinations: (1) Normally closed contacts on both thermal elements; (2) Normally open contacts on both thermal elements; (3) Normally open contacts on one thermal element and normally closed contacts on the other element.—*George Ulanet Company, 92 East Kinney St., Newark, N. J.*

Compression Spring Tester

New "No. 467 Bench Type Spring Tester" has been developed to provide a standardized production instrument for the rapid testing of compression springs, such as aircraft engine valve springs. The spring



is placed on the platform and the pointer is set at zero by means of an adjusting nut, a ram being lowered until the desired deflection is reached, at which point the corresponding load is read on the dial. Accuracy is guaranteed to within one-half of one per cent of the dial reading. Overall height, approx. 28"; base approx. 8" × 10"; load platform diam. 5"; ram diam. 3"; load indicator diam. 6⅝"; standard capacity 250 × ½ lb.—*John Chatillon & Sons, 85 Cliff St., New York City.*



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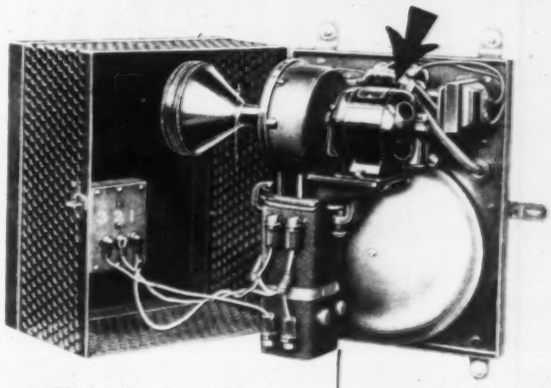

This carbon monoxide alarm, manufactured by Mine Safety Appliances Co., constantly analyzes the atmosphere for carbon monoxide gas. Since as little as .08% in the air might be fatal, this unit sounds a warning when .02% is reached. A 1/50 hp Bodine motor drives a small fan which is running continuously.

Carbon monoxide gas is an ever present danger in such places as fleet garages and chemical plants. This CO detector must operate dependably and without failure to protect the lives of workers. A reliable Bodine motor was chosen to operate this important instrument.

Bodine motors are widely used where dependability and accuracy are needed. Many instrument manufacturers have standardized on these high quality motors. Bodine Electric Co., 2244 W. Ohio St., Chicago, Illinois.

BODINE FRACTIONAL HORSEPOWER MOTORS

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Reduce maintenance repair of moving parts in instrument mechanisms.

AEROPOINT is the most outstanding improvement in years!

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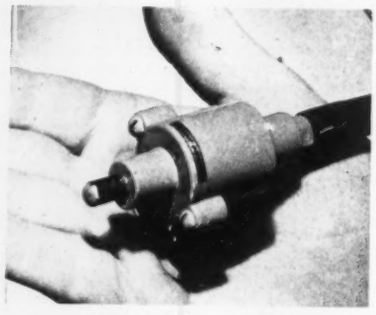
Midget Air Clamp

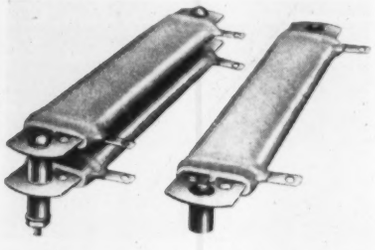
New Midget Air Clamp for assembly jigs and other multiple applications is said to be a low-cost pressure unit designed expressly for the aircraft industry to "save countless man-hours in all operations involving the joining by welding, riveting, or bolting of two or more component parts of any assembly." Claimed advantages over



mechanical clamps: (1) All Air Clamps in any set-up can be operated by a single master valve, whether there be two or several hundred in the operation involved. "Lock-up" and "release" of assemblies is instantaneous. (2) Compact size permits installation in cramped corners. (3) Special delicate adjustments are unnecessary, since Air Clamp ram holds with equal pressure at any point along its stroke. (4) Any desired group of "Midgets" can be controlled independently of any other groups in a given assembly. For example, in assemblies where certain primary numbers require locking up before secondary numbers are laid in, primary numbers can be controlled by one master valve, and secondary numbers by another valve, and so on. (5) Many kinds of light bench assembly jobs and delicate drilling operations can be facilitated by the use of Midget Air Clamps actuated by foot control valves. Midget Air Clamp delivers 80 lbs. pressure on a line pressure of 100 lbs. Stroke of ram is $\frac{5}{8}$". An internal return spring withdraws ram when air is exhausted from cylinder by the control valve. Prompt deliveries are offered for war industries.—*Mead Specialties Co., Dept. M-36, 15 So. Market St., Chicago, Ill.*

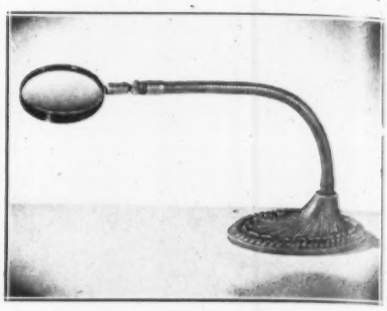
Strip Resistors

New "Vitrohm" strip resistors are especially suited to applications in aviation, radio, and installations where space limitations and high unit space watt ratings are important requirements. Several sizes are



available, ranging from 1¼" to 6" in length with ratings of 30 to 75 watts. Ohmic values for the 30-watt units range from 0.45 to 6,300; for the 75-watt units from 1.4 to 66,000 ohms. New resistors employ a strong, flat refractory core for the resistance wire winding. Terminals are mechanically banded and spot-welded in position on the core; core and winding are then sealed in a fused on Vitrohm enamel. Each unit is fitted with a self-sustained mounting bracket and spacer. Spacers and end brackets are riveted to metal strips that extend through core, providing additional heat radiating facilities.—*Ward Leonard Electric Co., Mount Vernon, N. Y.*

The Seerite
INSPECTION MAGNIFIER



Ideal for close precision work, this inspection instrument may be used to advantage any place in plant or laboratory where magnification is desirable.

The lens of this instrument is optically ground and polished and is availab'e in 3 in., 3½ in., 4 in., and 4½ in. sizes. Magnification is approximately 3 times. Lens is mounted on a 12 inch flexible arm which in turn is mounted on a black crystal weighted base. Reading glass is adjustable to any required position. Prices range from $4.00 to $6.00 depending on lens size.

Send for circular on full line of reading glasses and magnifiers.

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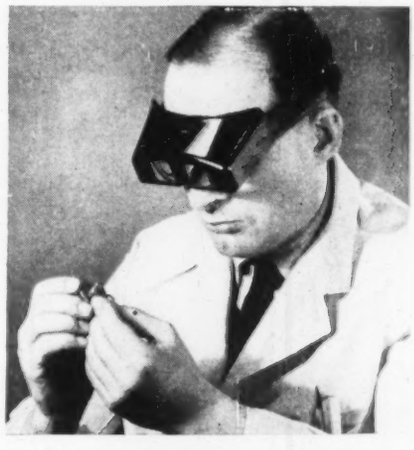

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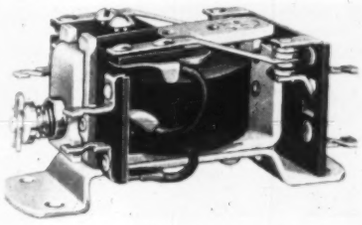
Midget Metal-base Relays

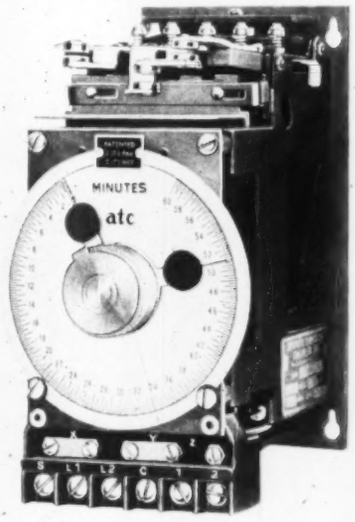
New "Bulletin 104" Relays are small compact remote-control units adapted to applications within their ratings where space is limited. These relays are available for



operation on a.c. and d.c. circuits. Standard relays are of the open type, front connected solder type terminals, double-pole double-throw, silver-to-silver contacts. Contacts are rated: 4 amperes up to 24 volts a.c. or d.c. and 4 amperes a.c.; 1 ampere d.c. from 25 to 115 volts. These new relays are vibration resistant up to ten times gravity in the energized position. The overall height from base to armature is 1¼".—*Ward Leonard Electric Co., Mount Vernon, N. Y.*

"Cycle-progress" Timer

Where timed operation on a stop-cycle basis is required for machines or processes, and where it is desired to have an indication of the time elapsed or time to end of



cycle, new "Series 2800 Cycle Progress Timer" will accurately control such applications as: die casting machines, molding presses, automatic quenching, soaking period control, etc. Telechron motor driven and equipped with a simple "no-locking" knob, this line of timers is available for operation from 110 or 220 volts, 25, 50 or 60 cycles. Contacts of ⅜" fine silver will carry loads to 25 amperes at 110 volts a.c., non-inductive. Red pointer (shown at zero of dial in illustration) indicates progress of time cycle; and black pointer (shown set at 51 minutes) is set by the knob to desired time limit. Dial diameter is 3⅞". Units provide for maximum flexibility, allowing for field adjustment of three colored slides and three bridges to select desired contact action for meeting various operating conditions. Load and timer's motor-clutch circuits are normally wired independently; but can be wired together by simply using a jumper. Timers may be supplied for resetting or non-resetting action upon power failure. A one-piece molded Bakelite terminal block accommodates bridge positions as well as all external wiring to clearly marked screw post terminals. A leaf-spring contact assures positive make-break contact action. Standard dials are 15 and 60 minutes; 2, 10, 20, 40 and 60 hours.—*ATC Company, Inc., 3¼ East Logan St., Philadelphia, Pa.*

WITH pride in the achievements of our employees whose production of optical instruments and other precision apparatus has won the commendation of the armed services, we accept with sincere appreciation the Army-Navy "E" Award "for high achievement in producing materials needed for war," the emblem of which now flies over our plant.

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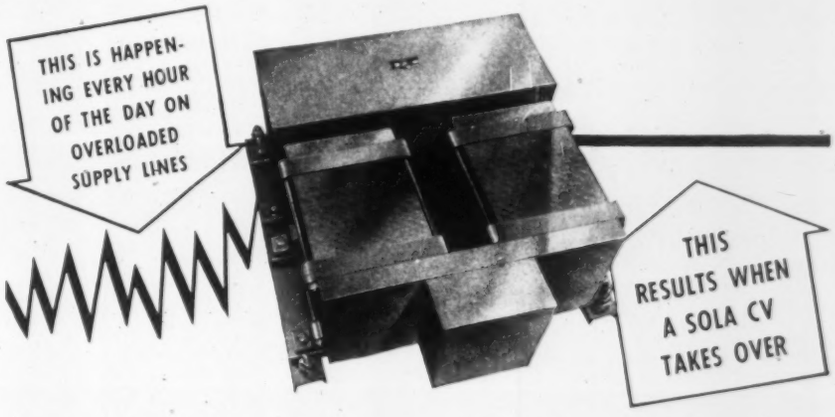

Stabilize your power supply at peak efficiency 24 hours per day

Your equipment, whether it is a vacuum tube, a laboratory instrument or a complex, electrically operated machine is designed for a rated line voltage. Any deviation from this value may mean damaged equipment, misleading results in laboratory research or a noticeable lack of uniformity in products and production schedules.

Sola Constant Voltage Transformers automatically provide perfectly regulated voltage that remains constant regardless of supply line fluctuations. They have no moving parts, are self-protected-against short circuit, and require no supervision. They're on the job 24 hours per day.

Standard designs are available in capacities ranging from 15VA to 10 KVA or special units can be built to your specifications.

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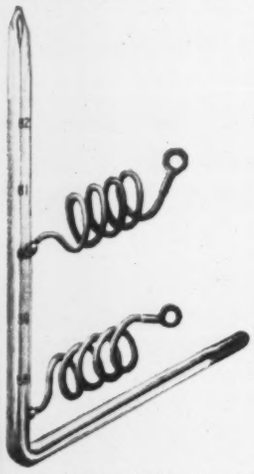

● Sensitivity of a hundredth of a degree is easily attainable. ● Top of mercury column visible at control point (where most important) because electrodes terminate at back of tube. No encircling metal bands! ● Available in angle form (illustrated) or conventional straight form. ● Send for brief, attractive bulletin.

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Prices and literature upon request

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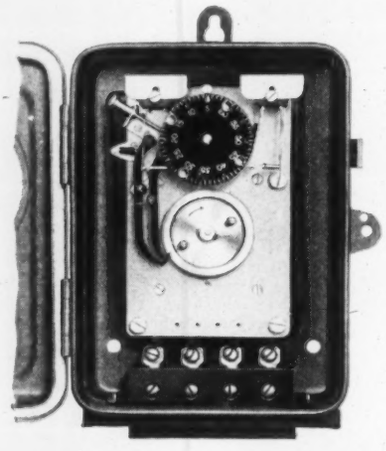
158 SUMMIT STREET • NEWARK, N. J

Contact-making Clock

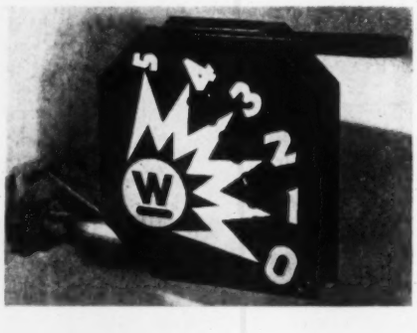
Where a.c. of commercial frequency is used, new Sauter Contact Making Clock Type CYC-4 is used in conjunction with maximum demand meters requiring "a very accurate and dependable impulse timing element." It also can be used as an impulse timer for various time recording instruments. New instrument's function is to emit 1 to 12 impulses per hour by momentarily closing a circuit at predetermined, fixed and unvarying time intervals. Operating pins are inserted into the 60-minute dial at the pre-selected intervals when an impulse



is to be given: one pin at "0" to give an impulse every 60 minutes; four pins spaced "0", "15", "30", and "45" to give an impulse every 15 minutes, etc. A cam serves as a vernier for the 60-minute dial the gear ratio being 12 to 1. It operates the first contact every five minutes but as the second contact is wired in series the actual impulses are emitted only when the operating pins in the 60-minute dial have closed the second contact. At these pre-selected intervals a short but positive contact (the standard setting of which is one-fifth of a second) is made. Motor is of the hysteresis type (450 rpm on 60 cycles), consumes approx. 3 watts, is self-starting and has ample torque for intended application. can be furnished for 110 or 220 volts and for any commercial frequency. It has an integral, sealed gear train selected for the proper ratio. Entire motor unit is easily interchangeable. Contacts are of pure silver rated at 1 ampere at 110 volts a.c.—*R. W. Cramer Co., Centerbrook, Conn.*

Operation Counter for Protector Tubes

New operation counter for protector tubes used on 13.8-kv. to 138-kv. transmission lines has six thin copper strips arranged in a small square counter box which is mounted on the vent pipe from the protector tube. When tube operates, part of the gas blast leaves through the small side horizontal tube on which the counter is mounted, blows off a copper blade, and the box falls into another angular position. Each time a blade is blown out, new position of counter indicates number of times protector tube has operated. Instructions give methods of mounting on practically all types of protector tubes. Blades are available for reloading, and the counter is provided with a loop-shaped strap which makes it possible to install and remove it by means of a hook stick.—*Dept. 7-N-20, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.*

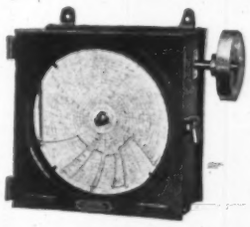


High-speed Filtration Apparatus

New "Filtrator" enables the laboratorian to separate and to collect both precipitate and filtrate in one-third to one-half the time required for ordinary gravity filtering. It comprises a vacuum chamber, receiving vessel and a unique new funnel, in a compact assembly with heavy base. Base is a low, stable metal casting which houses the control valve and vacuum connections. With the valve set at the "on" position, system is connected to the vacuum line. When filtration has been completed, valve is turned to "off" position. This does two things: it cuts off from vacuum system and allows air to enter vacuum chamber which can

then be lifted to remove beaker containing filtrate. Rubber pad on top of base serves as an air-tight gasket; it requires no grease as when bell-jar type of filtering assembly is employed. Top of vacuum chamber and the receiving vessel (any size beaker up to 400 ml.) rest on this rubber pad. The special funnel is inserted in the chamber opening by means of a rubber stopper. Thus, vacuum is applied within the chamber so that filtrate is drawn directly into beaker and need not be transferred. Patented one-piece porcelain Filtrator funnel is of double wall construction, having a solid outer wall and an inner wall with open slits. An 11-cm. filter paper is used and is folded in the usual manner for a 60° funnel. Filtrate and precipitate are confined well within paper's periphery and danger from leaking around edge is eliminated. Cone of funnel supports paper to its lowest point: tip cannot break off as often occurs with glass funnels where folded paper extends into delivery tube. Available pressure is exerted on largest possible area of paper in funnel without possibility of paper breakage. Width and length of inner-wall openings were determined by actual test so that a large, safe open area is used. An added advantage is that filtrate can flow through paper and into funnel tube readily. As is well known, when a glass funnel is employed, the paper is pressed against a flat surface, and the filtrate literally has "no place to go" between the filter paper and glass.—*Fisher Scientific Co., 711 Forbes St., Pittsburgh, Pa.*

Amthor



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12 or 24 hr.

Built for severe service. Users report 10, 12 or more years of trouble-free life. Powerful centrifugal speed-measuring element stays calibrated. Non-spill reservoir pen. Special chart paper. Rugged clock movement. Ideal for analysis of new War Effort jobs.

Immediate and intelligent attention will be given to your inquiries on all industrial speed measurement problems. Drop us a line today.

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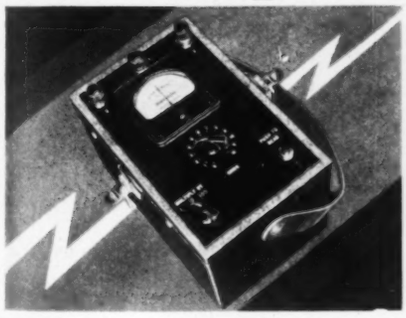

Protect equipment and workmen, and prevent loss of power . . . test your grounds with the VIBROGROUND! Direct readings on an open scale are obtained by merely pressing a button. Stray ground currents, AC or DC, do not affect accuracy. Write today for the Engineering Bulletin on the sturdy, portable, easy-to-use VIBROGROUND.

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437 S. DEARBORN ST., CHICAGO
Manufacturers of Electrical Instruments

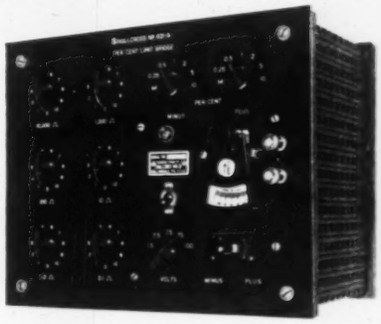
Explosion-proof Thermostats

New Underwriters-approved explosion-resisting thermostats are available in remote bulb style (illustrated) or with helical capillary bulb at top of housing (where

coiled capillary appears in illustration.) Range of all models is 40-90°F. Fixed differential of four models is 3°F.; four other models have differential adjustable from 3 to 22°F. Various contact arrangements are available, as are various motor ratings from ½ h.p. to 1 h.p.—*White-Rodgers Electric Co., 1209 Cass Ave., St. Louis, Mo.*

Percent Limit Bridge

New "No. 621-A Per Cent Limit Bridge" has been designed for quick and precise inspection of resistors to determine if they are within the specified percentage toler-



ance. Outstanding feature is that a selection of tolerance from 0.25% to 10% can be made and the "plus" and "minus" tolerances may be set individually and independently of each other. Thus, the "plus" may be set at 1% and the "minus" at 10% or vice versa; or either tolerance at any percentage (within the range) required. The working standard may consist of 6 decades totaling 1,111,110 ohms in 1-ohm increments. Other ranges to meet individual requirements are available. By setting the independently operated percentage dials to the "M" position this bridge is instantly ready for use as a Wheatstone Bridge (unity ratio) and the actual resistance of the units under test can be readily measured. Instrument is completely self-contained. A standard No. 6 dry cell furnishes the power for measuring low resistances. For higher resistances, an a-c.-operated rectifier tube supplies the power.—*Shallcross Mfg. Co., Collingdale, Pa.*

Uniform up to 2,000,000 cycles

★ Out of the flaming crucible of war which tries equipment as well as men's souls, comes this new DuMont Type 224 Oscillograph. And this is what it means to you:

First and foremost, its wide band Y-axis amplifier permits study of signals of frequencies far beyond the range of standard oscillographs. It has a faithful sinusoidal wave response—20 to 2,000,000 cycles, and comparable square wave response to 100,000 cycles.

Second, it is a more versatile oscillograph, providing extreme variety in the application of signal to the cathode-ray tube. Handy connections on front panel. Also a test probe with shielded cable, reducing input capacitance and eliminating usual stray pickup.

Third, it is housed for severe service out in the field as well as in plant or laboratory. Protective removable cover safeguards panel and controls when not in use, especially in transit.

Other interesting innovations and advantages. Measures 14⅛" h., 8⅝" w., 15⅛" d. Weighs 49 lbs.

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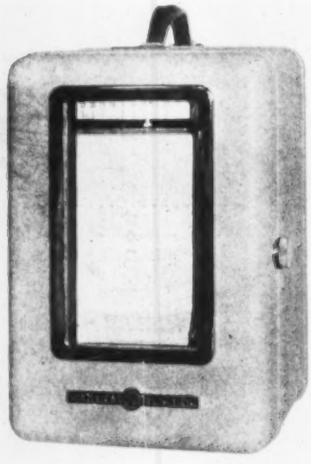
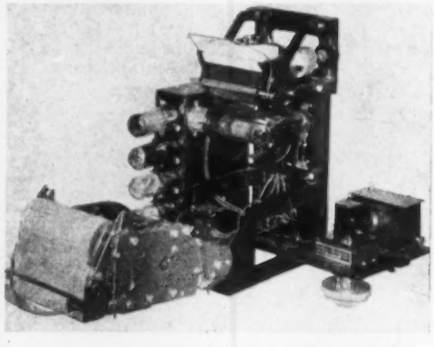
Optically-balanced Phototube-relay High-speed Recorder

Quintupled speed of recording has been accomplished in new design of "Photoelectric Recorder" which produces ink-on-paper records of rapidly-changing values: up to five cycles per second. (One cycle per second was highest speed of fastest model of original design first described in *Instruments* July 1931, page 403.) Operating principle, which remains unchanged, may be described as the automatic follow-up of the "pointer" of a sensitive low-period indicating instrument by the pen-arm of a



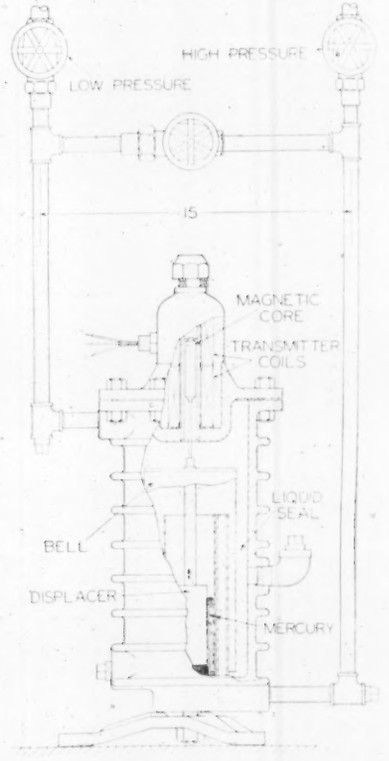
rugged recorder. The sensitive indicating (or "basic") instrument is usually a suspension galvanometer but other types may be incorporated to measure voltage, current, power factor, frequency, etc. Its "pointer" is a beam of light reflected from a tiny mirror which adds practically nothing to the inertia and damping of the moving element. Mounted above the basic instrument is the writing mechanism, the pen-arm of



which is co-axial with the basic moving element and likewise carries a mirror. An optical system is the only coupling between the two moving elements and is so arranged that when the two mirrors are *parallel*, the light beam is reflected from the upper mirror to the edge of a fixed dividing mirror whereby the light is divided equally between two phototubes. These phototubes are the prime relays of an electrical servo mechanism capable of driving the pen-arm across the chart in about a tenth of a second. Thus the pen-arm mirror is kept parallel to the basic-element mirror, and optical balance is automatically re-established at all times—provided only that the basic element extreme swings be within the 0.1-sec. speed-limit of the writing element. Otherwise the pen will lag behind the basic element, but without risk of "losing" it. *Chart speeds:*—The same standard chart drives are used as in previous models the highest chart speed available being 1.2" per second; and a choice of two-speed drives being available. *Dimensions:*—9½" × 9½" × 13"; chart width 4"; total weight of recorder 34 lbs.; semi-flush mounting available for switchboard installation. Easy accessibility of all parts (see Fig. 2) is a feature of new design.—*General Electric Co., Schenectady, N. Y.*

Low-pressure Flow Transmitter

New "Style H" transmitter, used in conjunction with standard Cochrane electric flow meter receiving units is designed specifically for the measurement of low static pressure gases where low differential and resultant low permanent pressure loss is of prime importance. Differential pressure created by flow is applied to the opposite sides of the oil-sealed bell with the pressure from the upstream connection being applied under



the bell and the downstream pressure above the bell. A metallic displacer in the central reservoir is submerged in mercury to a point where the bell and displacer just float when no differential pressure is exerted. A flow of gas resulting in a change of differential pressure raises the bell, lifting the displacer from the mercury with the change in buoyancy being just sufficient to give a bell movement proportional to the differential pressure. The translation of bell movement to uniform-chart readings is accomplished by the individually-calibrated cam common to Cochrane receivers. "Style H" transmitter is designed for differentials of 2, 4, 6, 8, or 10 inches of water. Standardization of design permits altering differential head by changing displacer and amount of mercury in central reservoir. Bell casing is designed for a maximum working pressure of 75 lbs./in.². Differential pressure in excess of the design differential will move bell to its upper limit: gas will bubble out from under bell with relatively little disturbance because volume of bell is large in comparison to size of high-pressure inlet pipe. Normal operation of meter is resumed when differential falls back to normal values. Ease of accessibility to transmitter interior permits quick and thorough cleaning of all parts—an operation often necessary on blast furnace and coke oven gases. Sealing oil level can be quickly checked through filling plug without removal of top cover. The same mounting bracket can be used in either wall or floor mounting of the unit.—*Cochrane Corporation, 17th & Allegheny Ave., Philadelphia, Pa.*

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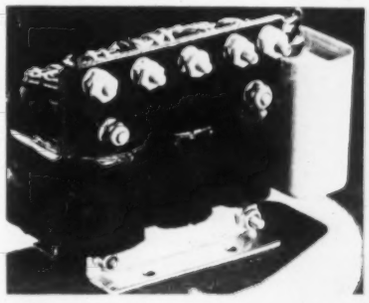
Three-phase to Single-phase Transformers

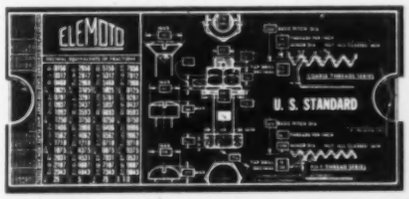
A new line of three-phase to single-phase transformers has been specially developed for operating instruments and accessories on aircraft. These transformers provide a single-phase, 115-volt or 26-volt

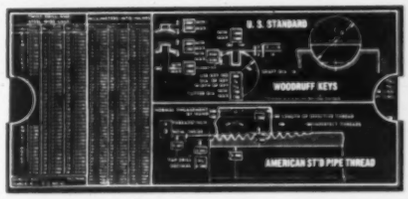


power supply from a three-phase, 400-cycle generator, without disturbing generator-phase voltage. "No. 68G447" has been specially developed for operating the radio compass and indicator lights. This is a 400-cycle transformer operating from a 115-volt, 3-phase generator. It supplies 115-volt amperes at 115-volts, single-phase, to the radio compass and 5-volt amperes, single-phase, to the 0.19-amp. T-1¾ indicator lights. These transformers operate satisfactorily in an ambient temperature range of 60°C. to minus 35°C. Operation is not affected at altitudes from sea level to 35,000 feet.—*General Electric Co., Schenectady, N. Y.*

Calculator and Reference for Shop and Drafting-room

New "Elemoto Slide" saves the time of designers, specification writers, foremen, mechanics, etc. It is made of heavy paperboard, 4"×9" with white figures and lettering on dark-blue background. Front side





(upper illustration) gives U. S. Standard dimensions for coarse and fine thread series. When the slide inside the housing is moved to the right or left the correct dimensions for each size from No. 0 to 1¼" are placed at the windows in the blueprint dimension drawings. All required dimensions, such as threads per inch, basic pitch diameter, head sizes, etc., are obtained with one reading. For convenience, this side also carries decimal equivalents of fractions and a useful table of U. S. Standard gages for sheet and plate iron and steel. Other side (lower illustration) is used to obtain dimensions for U. S. Standard (and smaller commercial sizes) for Woodruff keys; lower section of slide is used to determine American Standard Pipe Thread dimensions. Housing also carries on this side a table for changing millimeters to inches and a table of Twist Drill and Steel Wire Gages.—*Elemoto Sales Co., Teaneck, N. J.*

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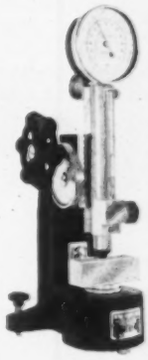

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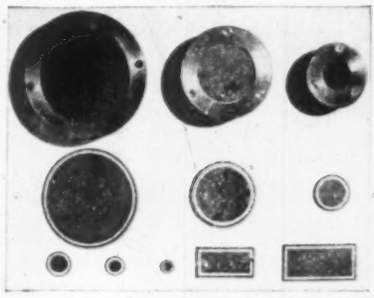

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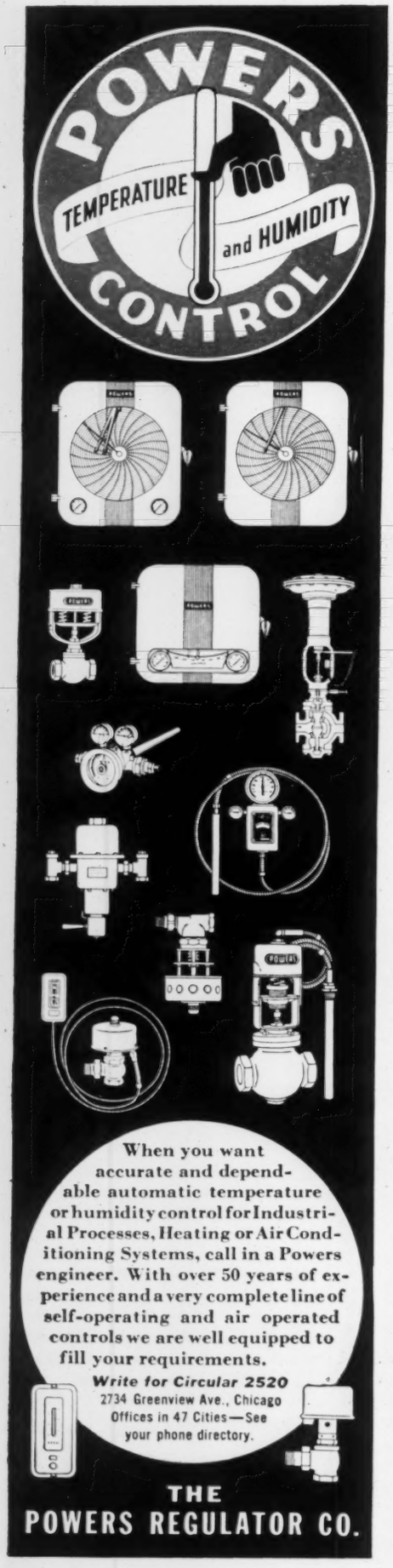
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Instruments in the War Effort

Detector for Under-surface Flaws in Steel

HEAT treated parts such as bearing races and similar cylindrical objects are being inspected for under-surface flaws by a simple magnetic method developed by P. H. Brace and C. S. Williams of Westinghouse Research Laboratories. Characterized by speed and accuracy, this electromagnetic test for flaws requires no contact with the inspected part.

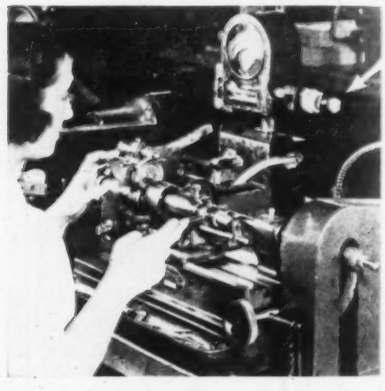
C. S. Williams of Westinghouse Research Laboratories demonstrating the principle of the sub-surface flaw detector. When used in production, an automatic machine provides four stations: (1) loading; (2) demagnetizing; (3) d-c. polarizing; and (4) scanning. The spindles would turn continually and the table index periodically.

When a symmetrical piece of steel is properly heat-treated and then magnetized, the external magnetic field is uniform. Any defect in the heat treatment such as a hard or soft spot changes the permeability of the faulty region and the magnetic pattern. In the new method, the heat-treated part is first demagnetized completely, then rotated at high speed and at the same time strongly magnetized, so that flux extends outward from the surface being tested. To test, this flux is explored with an electromagnet consisting of an alloy bar surrounded by a coil. Only variations of the magnetic field induce a voltage in the coil, which is amplified and indicated by means of an oscilloscope. The test piece is rotated synchronously with the cathode-ray sweep, so that a uniform field is traced on the tube screen as a luminous straight line, but faults show up in the oscilloscope trace as dips. A second trace on the tube screen acts as a reference line and carries twelve index points, corresponding to 30° angles around the test piece. By this means a fault can be spotted on the periphery within a few degrees.

Although the oscilloscope affords only a visual indication of the fault, it is possible to add a relay system to give an audible signal by means of a bell or buzzer, or even to operate automatic machinery for segregating defective pieces coming from a production line.

Timer and Lamp Simplify Operation

MOUNTED on and connected to an automatic timer, a small lamp (see arrow) simplifies the shaft-finishing operation at one of the General Electric Works. The timer and lamp are attached to a burnishing machine. When sufficient time has elapsed to provide the necessary finish on the shaft, the light warns the operator that the process is completed, thereby saving time and minimizing spoilage of metal.



Sodium Light for Microscopic Flaw Detection

MONOCHROMATIC sodium light is being used in war plants for surface inspection by microscope, because of its efficiency in the detection of pits, cracks, and flaws in materials, according to H. A. Breeding, of the General Electric Illuminating Laboratory.

Unusual perception of detail under sodium illumination is due to the monochromatic nature of the light: The eye, in common with other lenses, focuses only one narrow wave-band at a time. Other colors in the illumination tend to fog the picture on the retina. Minut

Less Fatigue... Faster inspection with the NEW MICRO-CHEK

Instrument size 6" x 2¼"

MICRO-CHEK with base plate only . . . $9.75

ADJUSTABLE ANVIL $3.00

Thread-gaging anvils for pitch diameter and thread leads are available.

LESS fatigue, faster inspections, are speeding up the gaging of millions of precision parts in more than 800 war plants which are now using the new Trico MICRO-CHEK.

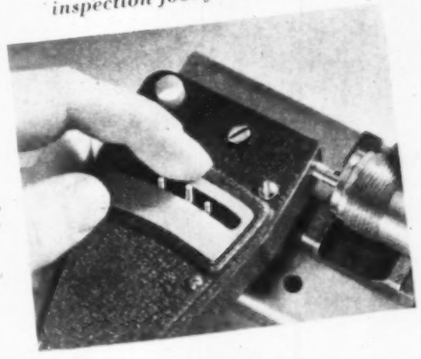
Many big industries have installed scores of these new comparator gages as a result of testing out a trial instrument. They found these advantages:

1. Greater speed with no sacrifice of accuracy; **2.** Faster reading, less eye-strain and fatigue on operators; **3.** Original accuracy continuously retained by re-setting with original master parts; **4.** Inexperienced workers quickly become accurate inspectors; **5.** Special fixtures or anvils for holding parts to be inspected require less accuracy and cost less to make.

Multiplies dimensions by 200.

A BRAILLE TYPE...

readable by finger touch... to open inspection jobs for the blind.



TRICO MICRO-CHEK

TRICO PRODUCTS CORP.
32 Goodell Street
Buffalo, N. Y.

details may be lost in examining an object under a light which contains all wavebands, but are detected when examining the same object under monochromatic light which contains only one wave-length. Sodium light is golden yellow, near the spectral region of yellow-green where eye sensitivity is maximal. A given amount of energy from sodium light produces several times as much illumination as the same amount of energy in white light.

As in the case of sodium lighting for night safety driving, monochromatic light for microscopic inspection is most effective when spread uniformly over a large area rather than concentrated in small bright patches. In this way an undistorted view of both size and shape of flaws present is obtained. For most effective results, the level of the illumination should be comparatively high, especially when the contrast between flaw and surrounding material is low.

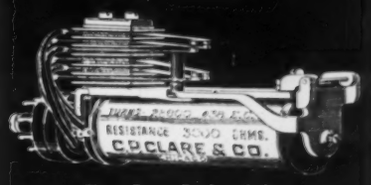
It is helpful in searching for cracks and blow holes to treat the part with either a light-absorbing or light-reflecting dye, the dye depending on the nature of the surface to be inspected. The dyed surface should be cleaned thoroughly before inspection. This procedure increases the contrast between flaw and object to the point where many times smaller flaws can be detected.

Wire Insulation Tester

DEVELOPED at the Westinghouse Research Laboratory, the tester illustrated determines how much rough treatment wire insulation in military electrical devices will withstand. Re-

search engineer Charles B. Leape demonstrates how this tester, driven by a thousandths-horsepower motor, pulls the sample wire under the weight at the left. A fine still wire, welded to the bottom of the weight, scrapes the test wire. Pressure is increased by adding weights until a tiny lamp (lower left) signals that the insulation has been scraped away.

This CLARE Relay Can Take the Place of Many



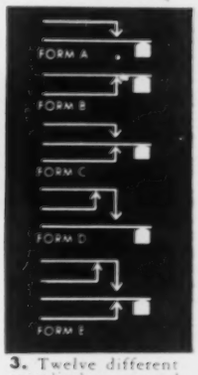
Clare Type C d. c. Relay

■ This rugged multiple-contact relay permits innumerable contact arrangements. Permits designing to small size, with a lesser number of relays; and facilitates maintenance. Adapted for use in electronic control devices and for sequence control and interlocking operations. Ideal where unusual arrangements of relay control are desired. Here are the reasons why:

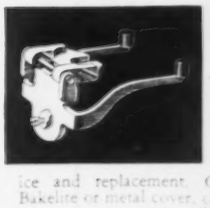
1. Contact springs employing any of the forms illustrated can be furnished.

2. Spring pile-up insulators of heat treated Bakelite which permit punching without cracks, have minimum cold flow and low moisture absorption content. Assembly locked together under hydraulic pressure. Withstands heavy breakdown tests.

3. Twelve different standard or special types and sizes of contacts can be furnished. Contacts are overall-welded to nickel silver springs. Sizes range from .062" silver, rated one ampere, 50 watts, to .1875" tungsten, rated four amperes, 500 watts.



4. Spring bushing insulators are Bakelite rod made by a patent process. Strong, hard, long wearing. Essential where heavy contact pressures are employed, where vibration exists, or heavy duty service is desired.



5. Armature assembly single or double arm. Has stainless steel shaft operating in a marine brass yoke. Heel piece, coil core and armature are magnetic metal carefully annealed. Designed for d.c. service.

6. As illustrated, relay has octal base pins for mounting for easy service and replacement. Other mountings and Bakelite or metal cover, can be supplied.

• • •

This relay is an example of Clare "custom-built" design and construction. Clare engineers will "custom build" a relay to meet your special requirements—one that will reduce your overall relay cost and simplify your design problem. Write for catalog and data book. C. P. Clare and Co., 4719 West Sunnyside Avenue, Chicago.

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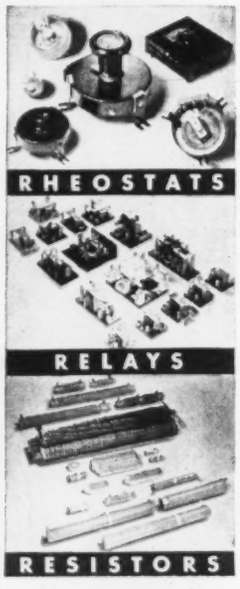
This is just another of the many instances where Ward Leonard Controls developed for peace time service meet a vital need in war activity. If your war work requires any form of electric control, you probably will find exactly what you want in the Ward Leonard Line.

Portlight Wiper



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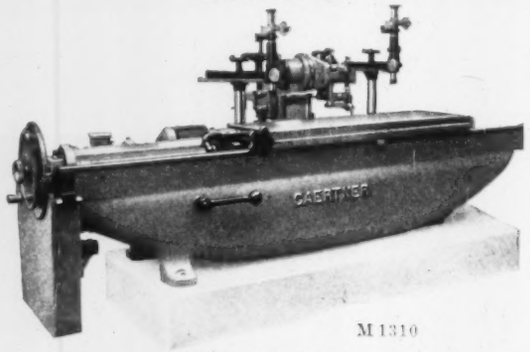

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Speed: 10 to 45 lines per minute

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In order to save valuable time, please indicate type of work and accuracy required, in inquiry.

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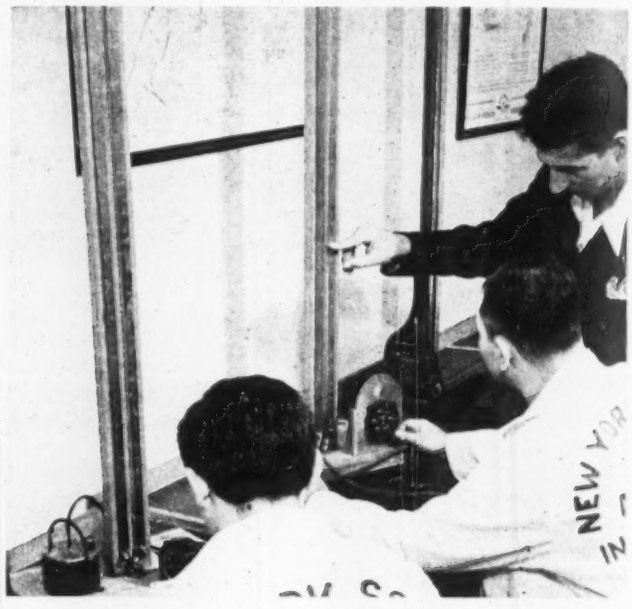
A Graduate of the N.Y.S. of A.I. Writes about His Training

By LOUIS JOSEPHSON

THE first few days at the school are a myriad of formulas, mechanical drawings, humming drill presses and spinning lathes. You think that the madly assorted theories and flying bits of metal will never assume their proper proportions in your suddenly crowded feverishly-working mind.

Then it happens! The formulas become keys to problems in gravitation, dewpoint, and electrical theory. The pencil and triangle follow your will and produce working drawings you never dreamed you could do. And the endless patient coaching of the shop instructors coax amazingly accurate machined parts from your unbelieving hands.

Now your tool kit, which the school ably and economically supplies, comes into more active use, for you are now ready for your first instrument, the galvanometer in all its forms and makes. This instrument is the base for all electrical indicators in use today.



Students using manometer to calibrate air speed indicators.

After some small difficulty in adjusting your touch to these extremely delicate mechanisms and learning to use your jeweler's eyepiece, you actually begin to repair and calibrate them. You learn to solder copper alloy hairsprings so fine that a heavy breath will distort their shape. The use of the Wheatstone bridge and other testing apparatus becomes part of your rapidly-growing knowledge in things electrical.

As I progressed to the pressure instruments and solidified my acquaintance with the students and the teachers, I could not help but notice the mutual confidence and harmony which existed among all in the school—student and teacher alike. During the six months of study it was only natural that I became more intimate friends with my classmates. I remember them with the nostalgic regret one feels at having to be far from friends. Kaufmann, Caress, Grubstein, Zerylnick and the rest. Sounds like the Notre Dame backfield, doesn't it, but all a coöperative competent class and all well established now in a field they know and enjoy working in.

However, I must stop reminiscing and extract myself from among the pressure instruments which, by the way

Precision TIME MEASUREMENT

Automatic or Manual Controls

NUMEROUS MODELS TO MEASURE TIME IN UNITS OF .01 SEC. TO 1 HR.

• Standard Electric Stop Clocks are rugged, dependable instruments. Controls may be custom built to suit special requirements. Sturdy manual reset. Attractive bakelite case for surface mounting or flush panel mounting.

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Flight Test Instruments for directional and horizon gyro, turn and bank, and rate of climb.

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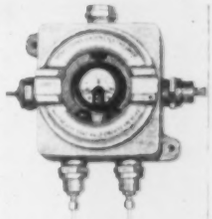
PIONEER BUILDERS OF SPECIAL ELECTRONIC INSTRUMENTS

3 *ways to* BETTER PLANT SAFETY . . . .

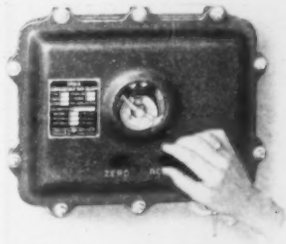
Through Accurate, Continuous Gas Determination!

M•S•A *EXPLOSION-PROOF* COMBUSTIBLE GAS ALARM



For safe and continuous sampling in atmospheres where combustible gases and vapors may be present, providing instant warning when gas concentrations exceed a predetermined limit. Contained in an explosion-proof condulet, with outer controls for resetting and checking, each instrument is calibrated for a particular gas or vapor, and operates warning signal at any pre-determined point. **Bulletin DT-2.**

M•S•A COMBUSTIBLE GAS ALARM



This instrument provides high precision in combustible gas determination, and can be used with an external pump capable of drawing samples through multiple lines over long distances to a convenient central location, remote from hazardous atmospheres. Operates any type of electrical warning signal; can be employed for ventilation or process control, and may be used with recording potentiometer. **Bulletin DT-1.**

M•S•A MULTIPLE SAMPLING COMBUSTIBLE GAS ALARM

A complete panel installation for continuously measuring combustible gas hazards at a number of sampling points, employing the M.S.A. Combustible Gas Alarm with multi-way sampling valve. Valve enables analysis of four, six or eight localities by the single alarm; rotating indexing drum automatically shows by visible number the line under test at any time. A recording potentiometer can be provided for continuous record of combustibles present in sampled atmospheres. Installation is furnished assembled. Details on application.

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BECAUSE . . . *IRC offers "best product" and "most complete line."*

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YES . . . we are proud of our Submersion type units. They are now available in a wide range of sizes to cover practically every requirement in defense and non-defense applications.

These units are designed to take the most extreme of Navy tests, which consist of five complete submersion cycles under salt water over a very wide range of temperatures.

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May we have an opportunity to cooperate?

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are as follows: simple and sensitive altimeter, low-range and high-range air speed indicator, and manifold pressure gage.

Then follow the more advanced instruments, the tachometers—centrifugal and chronometric, the bank and turn, the compass, and Autosyn remote indicators. These are in great use today due to the increasing number of multi-motor planes in operation.

Finally, toward the end of the course, the most important and the most sensitive navigating instruments in use today: the Sperry Gyroscope, Horizon, and Direction Finder. These required the most concentration and practice to master. Knowing that they were the instruments that made the Sperry bomb sight and blind flying possible, somehow lent a thrill to this study.

Then, to renew and keep fresh in the mind the material assimilated in the entire period, the last week is left to review the entire range of instruments in the course.

From there I cannot say. The course is finished, the aircraft industry is gigantic and the country is at war. The Service? Or industry? Each has a bit for you to do to help. The choice? It was mine. It can be yours.

Importance of Electrical Instruments

(Continued from Page 463)

instruments are important to aviation and many other industries, and in the interest of efficiency we must train our future mechanics in all phases so that we don't have to send back to the factory for replacements. We don't have time to get replacements. We want to spend that time in getting our equipment ready for immediate use so that our bombers and fighters can all accomplish their missions to hasten the day of Victory. ...— ...— ...— ...—

Instrument Mechanics and the War

(Continued from Page 464)

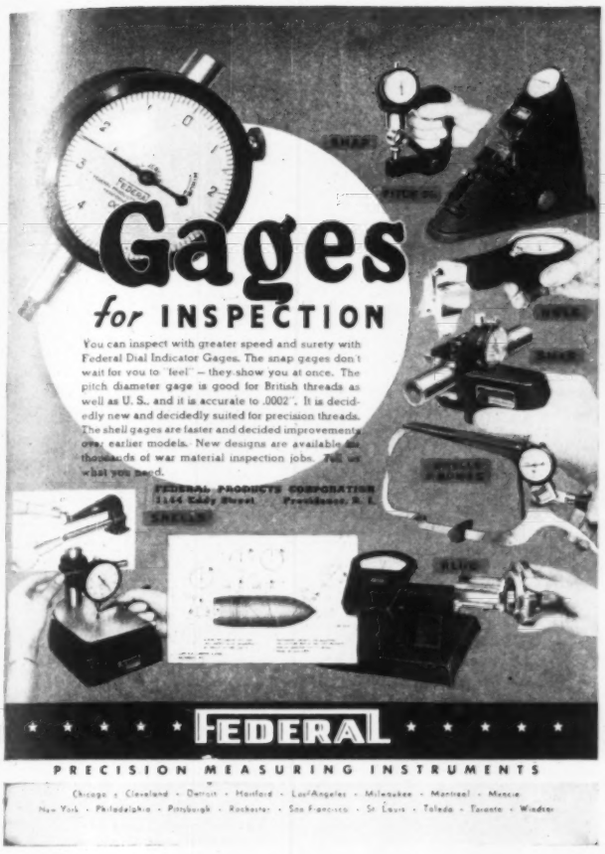
in this lucrative field. Some of the airline companies are interested in securing the services of women with the proper training in this field.

Metropolitan New York is particularly attractive to the men and women interested in aircraft instruments. Within this area are found most of the country's great instrument construction companies—Pioneer, Sperry, Kollsman, Aeromarine, etc. These plants, because of their ever-increasing needs for skilled employees, absorb a majority of our graduates. The excellent working conditions to be found in these plants make instrument work exceedingly attractive to the graduate.

The calls come also from the great airplane construction companies of the country who are always on the look-out for competent installation men and women: Curtiss-Wright, Glenn Martin, Grumman and others.

The need in this time of emergency is great, and the need in the period after the war, we believe, will be just

Student making final adjustment of electrical instrument before installation in test panel.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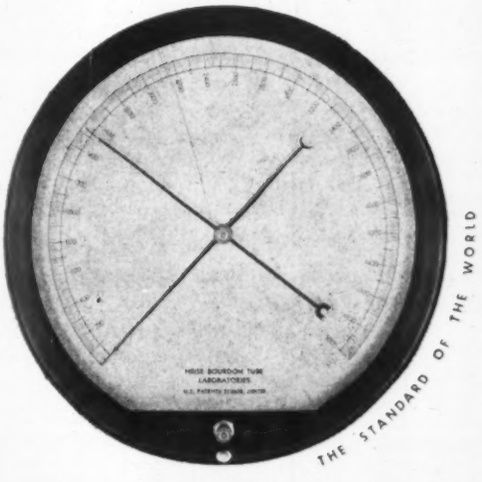

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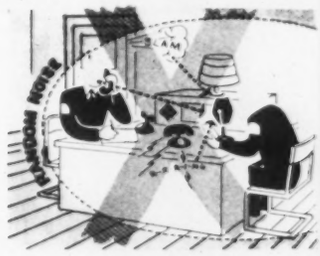
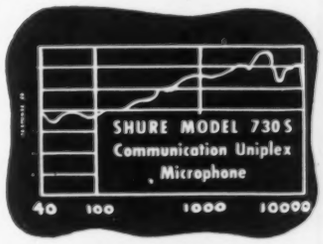
THE SHURE SUPER-CARDIOID MICROPHONE

In the illustration above and in the diagram at the left . . . the Shure Super-Cardioid Microphone rejects background noise and other unwanted sounds. It "Spotlights" the pickup of sound on the police operator. Contrast this with . . .



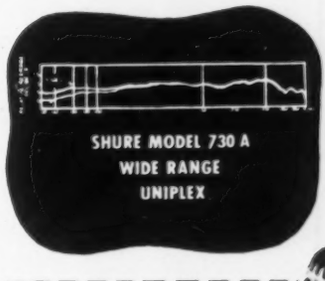
THE CONVENTIONAL MICROPHONE

This Microphone picks up sound from every direction as you can see in the diagram at the left. Background noise, reverberation, room reflection interfere with the important police call.



SPECIAL SPEECH RESPONSE

gives sharpness to the voice . . . cuts through noise and static—commands attention. The "lows" are attenuated—the "highs" accentuated for greater intelligibility. That's why . . .



THE CONVENTIONAL RESPONSE

is not recommended for communications, although it is excellent for music. In this diagram the wide range response of the conventional Microphone is shown as contrasted with the more efficient speech response of a specially-engineered Communications Microphone.

Write for Bulletin W172 for further information about Shure Cardioid Communication Microphones.

SHURE BROTHERS
Designers and Manufacturers of Microphones & Acoustic Devices
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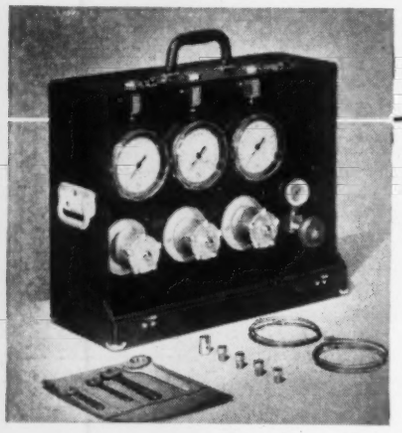
The GROVE Pneumatic Gauge COMPARATOR



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H-B THERMOMETERS

as great. Despite this, workers in this field do not appear in large enough numbers. The prospective student of aircraft instrument mechanics fears that he may perhaps lack sufficient academic background. He questions his ability to carry on this training without a knowledge of higher mathematics, physics, chemistry. Our experience has shown us that any literate American, in good health, can be taught instrument mechanics. In fact, we set our academic requisite at two years of high school, and we have found that given an individual with an earnest desire to do his bit, mechanically inclined or not, we can still turn out a mechanic who will do the job that must be done NOW to win the war.

Facts and Figures on Students

(Concluded from Page 472)

podiatrists, butchers, soda clerks, cotton brokers, insurance salesmen, furriers, dress designers, opera singers, are all preparing for our production line and maintenance work. Most of these trainees have never done anything mechanical. However, an intense desire to learn and a will to work hard are producing miracles.

Employment managers have been well satisfied with the product of these classes, and an expanded training program to meet industries' demands is being planned.

Instrument Panel for Combustion Tests

(Concluded from Page 448)

warm-air furnaces is measured directly by means of a special system of calibrated nozzles and plenum chamber.

Accessory equipment is available for recording of CO_2 and for surface temperature measurements. A separate sound-proof room is provided for noise level determinations.

The arrangement of test instruments shown in the illustration has been found to be helpful in promoting the procurement of accurate and complete data in combustion tests of domestic fuel-burning equipment. The particular requirements of other laboratories will, no doubt, suggest various modifications, but it is hoped that the arrangement described may be of general interest.

[EDITOR'S NOTE—In addition to the excellent photograph reproduced on the front cover, the authors sent us a large blueprint (34" × 44") comprising five detailed views. This combination drawing is too large for reproduction in a magazine of the size of *Instruments* but the authors can supply extra blueprints to directors of other laboratories.]

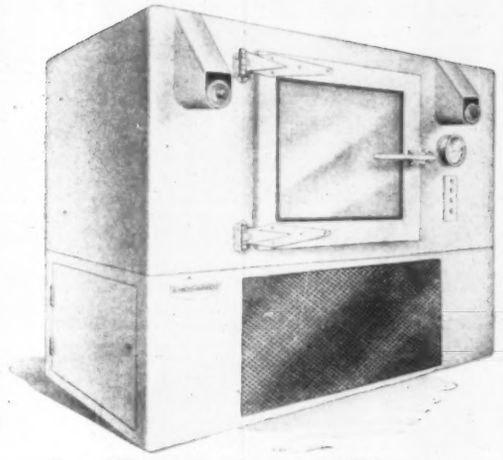
Stem Lag of Industrial Thermometers

(Concluded from Page 457)

eters differ greatly in the time necessary to come within 1°, a figure more in line with the accuracy desired by the user. Thermometers may be compared by comparing the time necessary to come to any percent of the reading if, and *only* if, the entire instrument be known to have one lag, and may not be divided into several lags as illustrated above. In thermometers of the type described, it is useless to try to determine speed of response by putting the thermometer in ice and then in boiling water, and measuring the time it takes the thermometer to indicate 0.90 (212-32) + 32 or 194°F. No difference of time could have been observed by ordinary methods, in the three thermometers described, yet one took seven minutes to come to within 1°, while another took less than three minutes. In spite of this, many workers continue to measure speed of response by determining L_{90}, the time for 90% of response.

It is not intended that undue emphasis should be placed on stem lag and stem errors. An instrument designed for and used at a definite fixed immersion, and kept at almost uniform temperature, has little error due to lag, but an instrument kept at room temperature and suddenly plunged into a hot medium must be left long enough for the stem to come to equilibrium, if a successful reading is to be attained.

KOLD-HOLD "Hi-Low"



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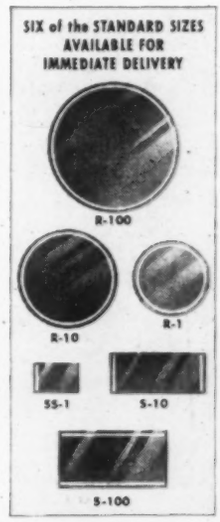

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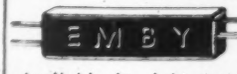

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If you are already thinking ahead to post war necessities, you may want to know more about how optical engineers could be of service in your business. If so, we shall welcome your letter.

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